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FOUNDED BY W. F. R. WELDON, FRANCIS GALTON AND KARL PEARSON

EDITED BY KARL PEARSON

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By L. BOLK, M.D.,
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THIRD ESSAY

ON THE TOOTH-GLANDS IN REPTILES AND THEIR RUDIMENTS IN MAMMALS

For a proper discussion of the phenomena described in the previous number of this *Journal*, it is necessary to draw attention to another phenomenon, which I came across in the course of my investigation. The meaning of this has caused me much difficulty. I will begin by stating the facts, and then discuss their significance.

As pointed out in the previous essay I began my odontological researches in embryos of man and other Primates, and the ontogenetical peculiarity which is the subject of the present essay was first observed in a human embryo.

In examining the series of human embryo *D* of my collection, I was struck by a phenomenon quite unknown to me. At the interval between the anlage of m_1 and m_2, the superficial epithelium sends a strand-like outgrowth into the subjacent tissue buccal to the dental lamina, and independent of the latter. The formation was seen on both sides and in both jaws.

Fig. 77

ACCESSORY BAND

This *accessory band*, as I will term it provisionally, was shorter than the dental lamina. On tracing the series in a backward direction the accessory band gradually approaches the dental lamina and finally both bands arise close together from the oral epithelium. Further back, the origin of the accessory band is moved to the buccal side of the base of the dental lamina, as is represented in fig. 77. Fig. 77 *a* represents the condition in the lower jaw. The section passes through the posterior part of the germ of m_2. Fig. 77 *b* is from the upper jaw, behind the anlage of this tooth. In neither jaw has the development of M_1 set in. The accessory band in the lower jaw joins the dental lamina at an acute angle. The structure of both bands is perfectly identical. In tracing the series further back, it becomes evident that the accessory band

extends to the hinder end of the dental lamina. However, its behaviour, especially its relation to the dental lamina, is somewhat different in the two jaws, as may be seen on comparing fig. 78 with fig. 79. In the upper jaw (fig. 78) the accessory band, gradually shortening, moves towards the free border of the dental lamina, ultimately disappearing a short distance from its posterior end. On account of this behaviour, one may conclude that there is a relation between this band and the dental lamina.

This supposition is strengthened by the relationships of the accessory band in the lower jaw as shown in fig. 79. After the union of the accessory band with the base of the dental lamina, the former does not shift to the free border of the latter, as happens in the upper jaw, but remains in connection with this base. The base is severed from the superficial epithelium, just above the point of junction with the accessory band. Thus the epithelial formation, now lying free in the mesenchyme, has become hook-shaped. It should be noted that this

Fig. 78

Fig. 79

hooked formation represents not only the dental lamina. It is compound in nature, the short leg, directed nearly horizontally, being the posterior end of the accessory band. This somewhat different relation of the two bands in the upper and lower jaws has no fundamental significance. The discovery of an accessory band in the human embryo *D* induced me to search for its possible occurrence in the other series at my disposal. I could thus determine whether I had to do with an accidental or with a normal phenomenon. To my surprise I found this formation occurred regularly in all human embryos examined. However, it is not always so strongly developed as in embryo *D*. In some the formation was very rudimentary.

Further examination of my human embryological material revealed peculiarities of the accessory band which possess some morphological significance. Fig. 80 will serve as a starting point for the description of these peculiarities. Both drawings (fig. 80) are from an embryo (Series *U*) older than the embryo *D*, from which figs. 77, 78 and 79 have been taken. For, while in embryo *D* the

development of the first permanent molar had not yet commenced, in the embryo *U* the enamel-organ of this tooth has reached a further stage of development, as shown in fig. 80 *b* which represents a section through this organ. When comparing fig. 77 with fig. 80, the difference in age must be taken into consideration. Fig. 80 *a* represents a section at the interval between upper m_2 and M_1. The dental lamina, and the accessory band on the buccal side of the lamina are easily recognised. The band shows a noteworthy feature. Its free border is bifurcated, terminating in short buccal and lingual branches. Undoubtedly this section of the accessory band possesses more than a superficial resemblance to the first stage of development of an enamel-organ. The two branches are connected with the oral epithelium by a short dental lamina. The resemblance to an enamel-organ merits special mention, for it is possible that an investigator, observing this formation, and having but a restricted amount of embryological material at his disposal, and therefore not in a position to control his observations, may suppose that he sees a rudimentary anlage of a tooth buccal to the normal set of teeth. Yet this supposition would be an erroneous one, for the resemblance is not real but only apparent.

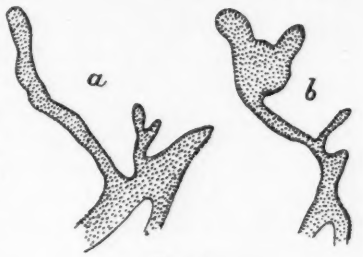

Fig. 80

That there is no question of an anlage of a tooth is proved by the fact that there is not the slightest indication of a dental papilla, the mesenchyme surrounding the bifurcated border of the accessory band showing no heaping up or concentration of nuclei. I draw attention to this fact because an investigator might mistake these outgrowths of the accessory band for rudimentary germs of the so-called prelacteal teeth. Now—as will be demonstrated later—the accessory band and its outgrowths have nothing to do with the hypothetical premilk-dentition.

Fig. 80 *b* represents a section at a more posterior point, one running through the enamel-organ of M_1. The accessory band is present and its origin has shifted towards the base of the dental lamina. The bands approach each other as the series is followed backwards, as occurred in the previous specimen. The section in fig. 80 *a* lies anterior to that in fig. 80 *b*, and shows the accessory band emerging from the oral epithelium, buccal to the dental lamina. The bands are independent of each other, as in section shown in fig. 80 *a*. In the posterior part of the dental lamina, behind the germ of M_1, the accessory band gradually shortens and approaches the free border of the dental lamina, as already depicted in fig. 78.

On comparing fig. 77 with fig. 80, an important fact concerning the growth of the accessory band comes to light. Fig. 77 *b* represents a section through the upper jaw of a younger embryo behind the germ of $\underline{m_2}$. Here the accessory

band takes origin from the buccal side of the dental lamina. Fig. 80 *a* gives a section through the corresponding point of an older embryo. A comparison shows that the accessory band, in the older embryo, no longer takes its origin from the dental lamina, as in the younger, but emerges from the superficial epithelium. Fig. 80 *b* clearly shows that in the older embryo the attachment to the dental lamina takes place at a more posterior point.

From this comparison one may conclude that there exists a genetical relation between the dental lamina and the accessory band, both being elongated during growth in a posterior direction. This conclusion is supported by the fact that the bands are extended together not independently. The epithelial formation, known as the dental lamina, is of a composite character on its buccal aspect, containing there not only the formations from which the germs of the molars arise—the dental lamina *sensu strictiori*—but also giving rise to the accessory bands. For this band is an outgrowth from the buccal side of the dental lamina, gradually decreasing in size as it passes backwards, almost to the posterior end of the lamina itself. Both bands progress backwards simultaneously, only topographical relations being changed during development. In the upper jaw the accessory band shifts its attachment to the base of the dental lamina and subsequently into the superficial epithelium. In the lower jaw it arises direct from the base, so that there is no possibility of any displacement towards the buccal side of the dental lamina.

This fact explains why the accessory band in a younger embryo is attached to the dental lamina, whereas in an older one it appears at a corresponding point as an outgrowth from the superficial epithelium. Having thus given a survey of the occurrence and of the developmental peculiarities of the accessory band in man, I shall proceed to discuss whether this formation is only a human peculiarity or is of more general occurrence. Anticipating the results of my inquiry, I may say that I have met with this band in a large number of different mammalian embryos both in the upper and in the lower jaw. I begin by describing its presence in other Primates.

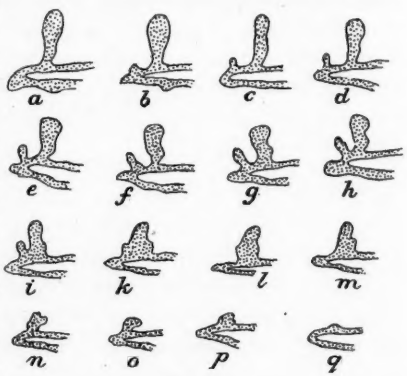

Fig. 81

In fig. 81 is represented a series of sections through the posterior end of the dental lamina of Tarsius spectrum. The thickening of the band indicates that the sections have passed through the germ or anlage of $\underline{m_2}$. In fig. 81 *b* the accessory band appears buccal to the dental lamina, as a slight outgrowth of the superficial epithelium. As shown by the succeeding sections this outgrowth gradually approaches the dental lamina. In fig. 81 *h* both formations are in close

proximity and fuse in the next section, exactly in the same manner as has been demonstrated in man. After this fusion the dental lamina rapidly diminishes in size as followed backwards.

Another example of the occurrence of an accessory band in lower Primates is illustrated in fig. 82, which represents a series of sections of the dental lamina in the lower jaw of Mycetes. The series begins with a section a short distance in front of the enamel-organ of M_1; the last section runs through the middle of the enamel-organ of this tooth.

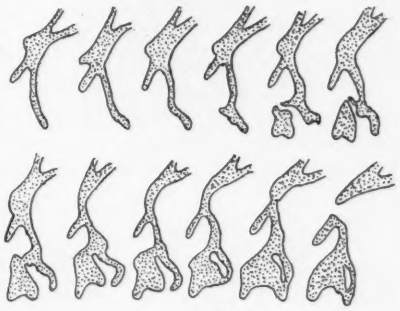

Fig. 82

I have already drawn attention to the fact, that the relation of the two bands differs somewhat in the lower and upper jaws. This is the case not only in man, but also in other Primates. As demonstrated by fig. 82, the base of the accessory band is attached to the base of the dental lamina, both bands originating conjointly from the superficial epithelium. This topographical relation holds all along the dental lamina. The separation of the laminar formation from the superficial epithelium takes place by the bands becoming free conjointly. The displacement of the dental lamina towards the buccal side in the upper jaw does not take place in the lower. This difference, however, is of little importance, resulting from the different manner in which the vestibular groove is formed in each of the jaws, a point which I need not dwell on now.

I could demonstrate the occurrence of the accessory band in other Primates which I have examined, but I shall restrict myself to the examples already given, remarking only that in Semnopithecus, Hapale, Chrysothrix and Pithecia this band is present. The accessory band may therefore be considered as a normal occurrence in the development of Primates.

I will add here a short description of an important peculiarity met with in one of my human embryos. Fig. 83 represents six sections through a part of the upper dental lamina of a Macacus cynomolgus. In the first three drawings the posterior part of the enamel-organ of $\underline{i}_1$ is to be seen. Now in fig. 83 *a* the accessory band, buccal to the dental lamina, is very well developed, growing out from the surface epithelium some distance from the dental lamina. In fig. 83 *b* the accessory band is strongly developed, and exhibits a bifurcated free end. By this bifurcation the accessory band undoubtedly shows some resemblance to the section of a normal tooth-germ at a very early stage of development.

In the succeeding sketches the bifurcation diminishes gradually, the accessory band itself decreasing in size. We have already drawn attention to a similar modification in a human fetus (represented in fig. 80) and I may

repeat the remark made *à propos* of that case: that the resemblance to an enamel-organ is a very superficial one, concerning only the external form. In the bifurcated part of the accessory band, there is not the slightest vestige of internal differentiation. There is no indication of ameloblastic cells. The surrounding mesenchyme shows no indication of a dental papilla.

The sections in fig. 83 are proof of the occurrence of an accessory band in the front part of the mouth. The accessory formation occupied the whole interval between $\underline{i}_1$ and $\underline{i}_2$. Behind the enamel-organ of the latter incisor a second vestige appeared and buccal to $\underline{m}_1$ a third. Behind the germ of this tooth the band approaches the dental lamina to fuse with it in the manner already described. The two epithelial formations in the front part of the

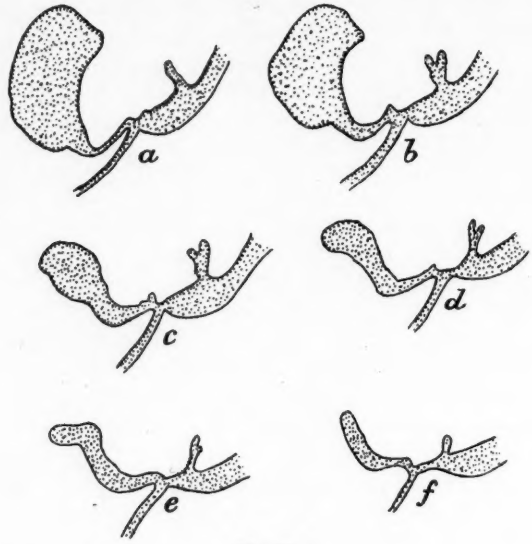

Fig. 83

mouth of this Macacus should be regarded as fragments of a single structure, for their situation and relation to the dental lamina are quite the same as in the posterior part of the mouth, where the band possesses a still more primitive character. The examination of embryological serial sections of other mammals has convinced me that the accessory band is not restricted to the group of the Primates, but is a formation appearing so often in the development of mammalian embryos, that it may be considered as almost a normal appearance. It is superfluous to enumerate all my observations concerning this point, for it has been described by other authors, such as Woodward in Erinaceus and Sicher in Talpa. None of these authors, who confined their attention to isolated specimens (to one species, Sicher, to one group of mammals, Woodward), has been able to ascertain whether or not the accessory band is a usual occur-

rence. Although I do not venture to assert that the accessory band occurs in all mammalian embryos, its occurrence nevertheless is so frequent that a description of its development should have a place in every systematic treatise. Now the accessory band, as will be pointed out later, is a rudimentary organ, possessing a striking relation to the tooth-band, but having nothing to do with the development of the mammalian dentition. Therefore conditions are not always favourable for determining its presence. It may happen that the embryo examined is one in which it is very rudimentary or perhaps wholly wanting, as is the case in all organs undergoing regression. On the other hand one may light on an embryo of the same species in which it is strongly developed.

I will give some idea of the variability of the accessory band in mammalian embryos by relating some of my observations.

Fig. 84

I select, first of all, a case in which the band was extraordinarily strongly developed. It is drawn in fig. 84, which represents a section through $\underline{m_2}$ of a Tragulus javanicus. The specimen was still in an early stage of its development, as proved by the enamel-organ, in which the formation of stellate reticulum has just commenced. A short distance from the dental lamina, and buccal to it, the deeper layer of the oral epithelium sends down a process, inclining laterally, into the subjacent tissue. This process—which is even longer than the dental lamina itself—is the accessory band. It shows its proper relation to the latter lamina by both processes taking a common origin from a thickening of the surface epithelium, the dental lamina at the lingual border, the accessory at the buccal. This circumstance is important as a means of explaining the nature of the accessory band. This thickening is very often met with. As a second example I give a section through the anlage of $\underline{m_1}$ of an embryo of Sus scrofa (Series *R*) in fig. 85 in which the thickening of the

Fig. 85

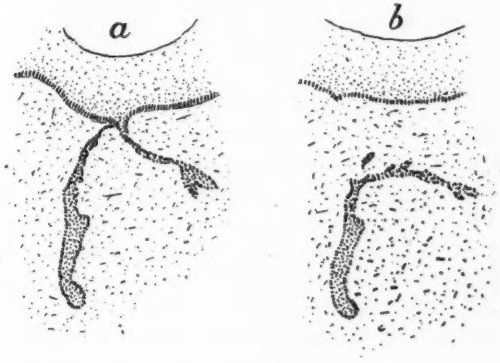

Fig. 86

superficial epithelium between the dental lamina and the accessory band (in this case bud-like) is very well demonstrated. As this figure shows, the deeper layer of cylindrical cells of the thickened plate of the oral epithelium passes continuously from the dental lamina to the accessory band.

The embryos of Equus caballus are very instructive regarding the nature of this band. I have found that the accessory band is rather strongly developed in this mammal, especially in the lower jaw. This is to be seen in fig. 86 in which are represented two sections through the posterior part of the dental lamina in the lower jaw of the embryo *D* of my collection. In section *a* the dental lamina and accessory band are still connected with the superficial epithelium; in section *b*, taken a little further back, the whole laminar formation lies free in the mesenchymatous tissue, and both parts of the well-known hook-shaped mass (cf. figs. 79 and 82). Fig. 86 *a* merits special attention. The free end of the accessory band bears the epithelial thickening already described in man and Macacus, and is not unlike the young stage of an enamel-organ.

The interpretation of such a thickening as a rudimentary tooth-germ becomes very attractive, particularly when the accessory band terminating in such a thickening is very short and emerges from the base of the dental lamina or even from the neck of a real enamel-organ. Such a case I have met with in Roussettus (Xantharpyia) amplexicaudatus, a bat of the Malayan Archipelago. In fig. 87 a representation of this formation is given from each jaw.

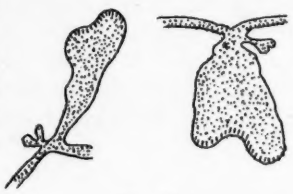

Fig. 87

The rather numerous representations which I have given of this thickening at the free border of the accessory band, may give rise to the idea that it is common. Yet, this is not the case. On the contrary, they are uncommon, not to say rare. The cases described and depicted in this paper are, with the exception of one, of which mention will be made later, all that I have observed in the course of my investigations. It seemed necessary, however, to give a brief account of all of these cases, in view of the discussion on the significance of the accessory band. Its interpretation has given me much labour and it was only after a thorough consideration of the different possibilities and after the discovery of some new facts in the development of teeth in reptiles, that I reached a definite solution of its meaning.

Of the possibilities to be taken into consideration I will discuss here only two. In the first period of my researches, when the accessory band was still a rather new and unknown phenomenon to me, I reflected on the possibility of it being identical with the lateral enamel-strand, which has been fully discussed in my previous paper. I thought it possible that in some cases the formation of the enamel-niche might occur in an irregular manner, so that its outer wall—the lateral enamel-strand—arising from the superficial epithelium, failed to reach and become attached to the enamel-organ. This idea of an in-

complete enamel-niche is not unlikely. Firstly this niche and the lateral enamel-strand are rudimentary formations, and we know that often such formations develop irregularly or in a defective manner. Moreover, the accessory band, lying buccal to the enamel-organ, is situated so near to the latter that the topographical relations of this band and the lateral enamel-strand do not differ much. Finally I recall the fact dealt with in my previous paper, that in the germ of the molars the enamel-niche is not infrequently situated immediately beneath the oral epithelium, so that the lateral enamel-strand is not attached to the dental lamina but to this epithelial layer. Now in such a case one has only to imagine that the attachment to the enamel-organ is broken away and a condition is produced resembling in all respects an enamel-organ with an accessory band.

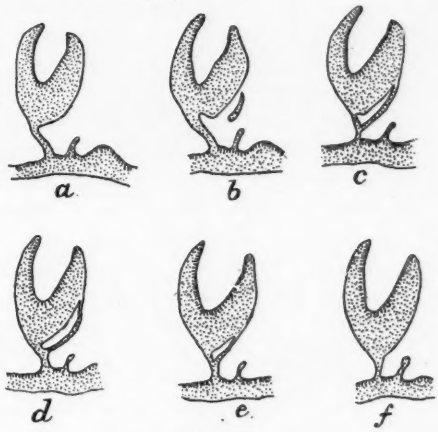

Fig. 88

Continued researches have convinced me however that this interpretation of the accessory band is quite erroneous. For if such an interpretation were right, the possibility of a section showing both a complete enamel-niche with the lateral enamel-strand and an accessory band, should be positively excluded. Now such cases do occur, and I have had the good fortune to examine a number of them.

A very fine instance is represented in fig. 88. Here are sketched six sections through the germ of $\underline{m}_1$ of an embryo of Sus scrofa (Series *W*). In fig. 88 *a* an accessory band is seen arising from the oral epithelium, buccal to the tooth-germ. In fig. 88 *b* the lateral enamel-strand appears, which, becoming complete in the next section, closes the enamel-niche laterally. Then the enamel-niche grows narrower and disappears in the last section. Now, these sections prove that there is no identity nor even an anatomical relation between the accessory band and the lateral enamel-strand. Both formations exist at the same time quite independent of each other.

In order to establish this fact still more conclusively, I have reconstructed in wax a portion of the dental lamina with a tooth-germ and the accessory band of the lower jaw of Mycetes. The reconstruction is represented in fig. 89 and establishes unmistakably the fact that the accessory band and the lateral enamel-strand are two independent formations.

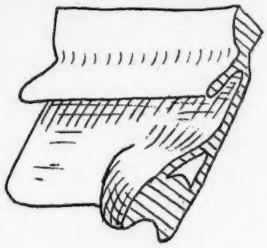

Fig. 89

Furthermore this model enables us better than any series of sections can do to get a good idea of the anatomical features of the accessory band. And this is necessary in view of the discussion relating to my second interpretation.

The accessory band is not described in the present paper for the first time. Several writers have observed and described it before. It is, however, the first time that its relative frequency and generality have been pointed out, most authors confining their attention to isolated cases and consequently considering that the accessorial formations were accidental. Not uncommonly such a formation has been regarded as a rudiment of the hypothetical so-called premilk-dentition, and certainly this view seems specially justified in those cases where the free border of the accessory band is thickened, bearing on section some resemblance to a young stage of enamel-organ. I have already given some examples of this condition.

The above view is discussed in the seventh edition of Tomes' *Dental Anatomy*. On p. 353 of this work a section is figured through the tooth-germ of a pig, showing a lateral outgrowth from the dental lamina. The author, however, expresses himself with some reserve with regard to this outgrowth. "If it is to be regarded as an aborted tooth-germ the writer expresses the opinion that it must be referred to a premilk-series. It is not definitely accepted as representing a tooth-germ by Marett Tims and others who have studied this specimen." I agree with this denial, for the outgrowth is a well-developed accessory band.

A somewhat divergent opinion is expressed by Woodward[1]. This author describes the accessory band in Erinaceus as follows (*l.c.* p. 563): "We find a slight but constant labial outgrowth from that portion of the dental lamina connecting the enamel-organ of the functional molar with the oral epithelium," and his conception of these formations becomes clear by what he writes on p. 583: "These labial growths in the molar regions are the last indications of an earlier set of teeth." The author, however, does not identify this earlier set of teeth with the hypothetical premilk-dentition, but, considering the functional molars as belonging to the replacing set of teeth, he concludes that these labial outgrowths of the dental lamina represent the much reduced milk-dentition (*l.c.* p. 584).

[1] "Contributions to the Study of Mammalian Dentition." Part D, Insectivora. *Proc. Zool. Soc.* London, 1896.

Thus while one group of investigators interpret the accessory band as a rudiment of the hypothetical premilk-dentition, another consider this formation as the reduced milk-dentition. Both agree as to the accessory band being a rudiment of a reduced set of teeth, either the premilk- or the milk-set. With this interpretation I do not agree.

Though accepting Woodward's view that the permanent molars belong to the replacing set of teeth, for I consider the milk predecessors of these elements as reduced, I cannot accept this author's opinion of the accessory band, which I consider erroneous. This is proved by the fact that this band appears not only in the region of the permanent molars but also—indeed very often—in that of the milk molars. I have already described and figured some cases of a well-developed accessory band buccal to a milk molar. These facts contradict Woodward's interpretation. Moreover I recall the fact, that in Macacus (*vide* fig. 83) there are rudiments of this band even in the frontal part of the mouth, buccal to the milk incisors.

On the other hand these facts seem to favour the interpretation of the accessory band as a rudiment of a premilk-dentition. Before entering into a discussion of this view, I will state my own standpoint relative to the problem of a premilk-dentition. Not only am I no partisan of such a dentition but on the contrary I strongly oppose both this conception and the possibility of a fourth or post-permanent dentition. For the present I cannot discuss these problems further—I intend to do so in a subsequent paper—and therefore I will confine myself to a brief statement. If we consider the phenomenon of the dentition in mammals as being identical with that in reptiles, then the hypothesis of a premilk-dentition as well as that of a post-permanent dentition seems probable enough, for reptiles usually have an indefinite succession of teeth. But in a future paper I hope to show that the processes of dentition in mammals and in reptiles are two quite different and heterogeneous processes, the similarity being only apparent.

Setting aside for a moment my general objection to the identity of the accessory band and the hypothetical premilk-dentition, I would direct attention to the special facts dealt with in the present paper. I lay stress upon the accessory as being a real band, extending uninterruptedly in a backward direction, being prolonged during the growth of the embryo in this direction, together with the dental band. If there was any relation at all between the epithelial formation in question and the premilk teeth, one would expect to find not a continuous band but isolated germs. And these germs should alternate with those of the milk-dentition. In view of the fact that in mammals the elements of the milk-dentition and those of the successional set of teeth alternate regularly, it seems to me necessary, if accepting a premilk-dentition at all, that equal topographical relations must have existed once between the elements of the milk- and premilk-dentitions. According to my observations this is not the case. This discrepancy I count of no importance as I repudiate wholly the hypothesis of a premilk-dentition.

I will state my own views as briefly as possible as to the significance of the accessory band. As mentioned already my conclusions are based on researches on the development of the teeth in reptiles.

In the course of this inquiry my attention was drawn to the very interesting relationship existing between the origin of teeth and the system of glands, which is often so profusely developed in the mouth of these animals. As is well known the system comprises several groups. There is one group, which takes origin from the palatinal epithelium and is therefore situated medial to the teeth. These glands—glandulae palatinae—are of no importance to us here. A second group is situated lateral to the teeth. These glands, known in literature as glandulae labiales (a denomination which, as will be shown, is not quite correct), are developed usually in both jaws, but may be absent in the upper jaw.

The first anlage of these glands is represented in fig. 90. This figure shows a transverse section through the epithelium of the lower jaw of a young Hemidactylus frenatus. Whilst this epithelium is built up in general by a single layer of cells, there is a zone, corresponding to the upper margin of the jaw,

Fig. 90

Fig. 91

in which the oral epithelium is thicker, consisting of two layers of cells. This thickened zone is continued medially into the dental lamina, bearing at its free border in fig. 90 an enamel-organ in a young stage of development. Laterally this thickened zone penetrates the subjacent mesenchymatous tissue, forming a short band situated labial to the dental band. This epithelial formation will produce the glands, and should be distinguished as the "glandular band." In the stage shown in fig. 90, there is nothing to be seen of a differentiation of glandular organs, the band extending as far backward as the dental lamina. It is very obvious that the dental band and the glandular band are formations of the same matrix and that there exists a close relationship between them. The layer of very typical cylindrical cells, composing the dental lamina, is continued—as demonstrated by the figure—uninterruptedly into the glandular band.

A somewhat older stage of development is shown in fig. 91, in which a section is reproduced from the lower jaw of a young Lacerta agilis. The relation of the dental lamina to the glandular band has grown more distinct. The covering epithelium still consists of a thin layer, but in this case, as in the

previous one, there is a thickened middle zone, the medial border of which penetrates deeply, forming the dental lamina, which bears at its buccal side a well-developed enamel-organ. The dental lamina and enamel-organ are situated lingual to the os dentale. The glandular band is also present, emerging from the lateral border of the thickened region. It penetrates rather deeply into the mesenchymatous tissue. In this section (fig. 91) the lamina terminates in two bud-like thickenings, the first indications of a gland. The glandular band extends buccal to the os dentale.

In fig. 92 a further stage of development is shown by a section through the lower jaw of Cyclodus Boddaertii. The thickened epithelial plate has grown

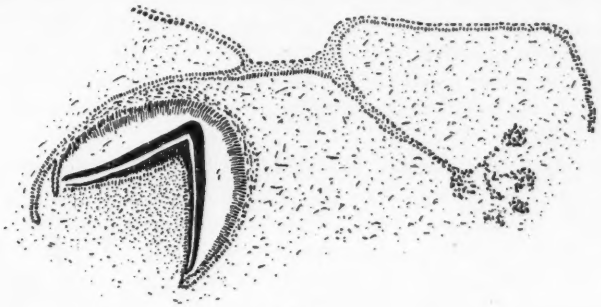

Fig. 92

narrower, by which fact the difference between this epithelial zone and the epithelial layer covering the other parts of the jaw is more accentuated. In consequence the contrast between both epithelial bands—the dental and the glandular—has become still more evident. They appear as buccal and lingual prolongations of the thickened plate, while sunk into the depth of the underlying soft tissue. A rather large and ramified gland emerges from the glandular band. This gland corresponds topographically to the tooth on the dental lamina, and effects a close relationship with the latter in the course of further development.

Finally I give in fig. 93 a section through the lower jaw of Draco volans, to demonstrate once more the topographical relations between the dental lamina and the glandular band at a more advanced stage of development, and specially to draw attention to the relation of both bands to the os dentale.

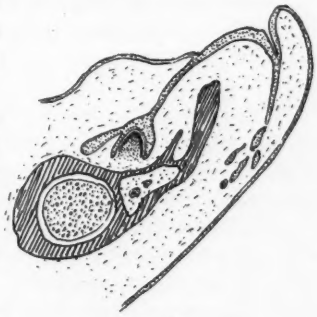

Fig. 93

Figs. 90, 91, 92, 93 establish beyond doubt that in reptiles the development of the glandular band, from which the so-called glandulae labiales take origin, is closely connected with that of the dental lamina. Both proceed from a common

epithelial matrix. And therefore it seems to me preferable to distinguish the glands shooting off from the band described above as tooth-glands and not as lip-glands, as is usually done. For even without laying stress upon the fact that lips, in the accepted sense, are wanting in reptiles, the further history of these glands justifies the name I propose. It has been mentioned already that the glandular band gives rise to the development of a gland opposite to every tooth formed from the dental band. Therefore there are as many glands as teeth, whilst the interglandular parts of the band degenerate and disappear. Thus the glands become separate organs, each with its own excretory duct. Originally the excretory ducts open on the surface in all reptilian embryos. This condition may persist during life, in which case a groove is usually formed, bounded on the medial side by the os dentale, laterally by a fold of soft tissue, on the bottom of which the excretory ducts open. By the development of this protecting wall of soft tissue there comes about an anatomical condition, not unlike that in mammals with real lips. Hence the naming of these glands, glandulae labiales.

In most cases, however, the thickened plate between the dental lamina and the glandular band is converted into special sheaths around the teeth. In consequence of this the excretory duct of a gland, belonging to a tooth, opens into the narrow cavity between the tooth and its sheath. The topographical relation between tooth and gland then becomes a very close one. Such a condition occurs in the Iguanidae, as may be seen in fig. 94, showing a section through the upper jaw of a young Iguana sapidissima. This figure needs no further explanation.

Fig. 94

Having given this short summary of the development of the glandular band in reptiles and established the genetical relation between this band and the tooth-band, we return to the proper subject of the present paper: the accessory band, which appears in connection with the dental band in mammalian fetus. I think the foregoing facts throw light upon the true nature of this band.

I have already given my reasons for not accepting the current opinion of the significance of this band. Personally I think this accessory band is the rudimental homologon of the glandular band in reptiles. To prove this absolutely is not possible, as in so many problems of the same nature. My conviction is founded upon the several corresponding points between both bands. On the other hand I lay stress upon the fact that the opinions of other writers, too, are mere suppositions, and none I think is so broadly based on fact as this inference of mine.

An important analogy is the common anlage of tooth-band with accessory band in mammals, and tooth-band with glandular band in reptiles. In reptiles the glandular band appears as an outgrowth from an epithelial mass, from

which also the tooth-band emerges, so in mammals the accessory band arises from the mass, which gives origin to the tooth-band. This thickened superficial plate between the two bands, which is so characteristic of reptiles, is sometimes fairly well seen in mammals. In fig. 85 (Sus) and fig. 84 (Tragulus) the intermediate plate is clearly demonstrated. A comparison of these figures with figs. 91, 92 will serve to strengthen the homology of accessory and glandular bands. The only difference between the anatomical conditions in mammals and reptiles in these four figures is the absence of glandular ramifications at the free border of the accessory band. This fact may indeed be utilized as an argument against the proposed homology. But the suggestion is not a sound one. For, what I was unable to observe in Sus and Tragulus, was seen by me in other mammals. Special mention has been made already of all cases in which thickenings and vestigial ramifications came under observation at

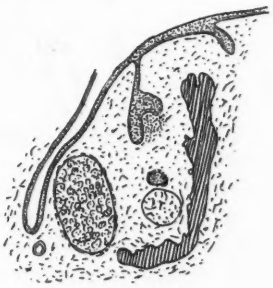

Fig. 95

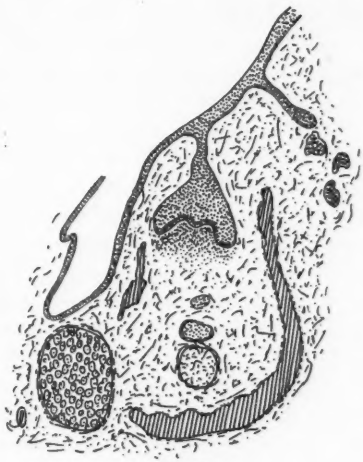

Fig. 96

the free margin of the accessory band. I refer the reader to figs. 80 (Homo), 83 (Macacus), 87 (Roussettus), and 86 (Equus). I am convinced that these thickenings are really vestigial glands, degenerating during later development. Besides, the whole accessory band atrophies.

There exists between the accessory band of mammals and the glandular band of reptiles a similarity in a genetical, topographical and functional sense.

The similarity from a functional point of view is proved in only an imperfect manner. For it is only a supposition of my own that the thickenings at the margin of the accessory band are vestigial glands. Fortunately, however, I am in the position to establish the correctness of my assertion, having had the good fortune to come across a mammal in which this band shows unmistakably real glandular ramifications. This happens in the mole. In this

animal the accessory band is strongly developed and apparently is not atrophying so rapidly as in the other mammalian embryos studied by me. In its general features and relation to the dental lamina it very much resembles the glandular band of the reptiles, as is apparent from fig. 95, representing a section through the lower jaw of a somewhat older embryo of the mole (Series *N* of my collection). Both bands emerge separately from the superficial epithelium, and the zone of the covering epithelium, extending between both bands, is thickened as in reptiles. The section in fig. 94 runs through the germ of $\overline{M}_2$. In this stage of development, the accessory band possesses still an undifferentiated free border.

A more advanced stage of development is represented in fig. 96 (Series *NN*). This section, too, runs through the enamel-organ of $\overline{M}_2$. The figures are drawn at corresponding points, and are therefore directly comparable. In both, the Meckelian cartilage with the os dentale are to be seen. In the concavity of the latter, the Arteria mandibularis is situated with the accompanying nerve.

The changes which have taken place concern principally the accessory band. It has penetrated more deeply into the mesenchymatous tissue. Now, though it terminates in the section shown (fig. 95) in a free border, there are three sections of a tubule to be seen situated close to the free edge. On studying the succeeding sections it became evident that this tubule is really an outgrowth from the margin of the accessory band.

We have thus a direct proof that the accessory band in mammals can still produce glands or at least glandular organs. In addition, the very close resemblance of fig. 96 from a mammal, to fig. 94 obtained from a reptile, should banish all doubts and prove conclusively *that the reptilian glandular band and the mammalian accessory band are homologous structures.*

The further developmental history of the glands in the mole is unknown to me. I do not know whether they become functional organs in the adult or atrophy after birth. The embryo *NN*, from which fig. 96 was obtained, was the oldest specimen in my possession, and it was certainly in the last phase of its intrauterine development.

In the publication of the present paper I have aimed at a double purpose. Firstly to make known new facts concerning the development of the dentition in mammals and reptiles, and secondly to enable odontologists to obtain a more exact knowledge of the so-called vestigial premilk-teeth. For I am convinced that many epithelial formations in a mammalian embryo described in literature as vestigial premilk-tooth, are in reality rudiments of the reptilian glandular band.

ON RARER OSSIFICATIONS SEEN DURING X-RAY EXAMINATIONS[1]

By CHAS. THURSTAN HOLLAND,
Liverpool

Routine examination of the body, particularly of such parts as have been the seat of accident, often raises doubts concerning whether the appearances seen are the results of force or of development. This is particularly the case as regards the foot. It is true that the accurate researches carried out by the late Prof. William Pfitzner[2] in the closing decade of last century give as complete an account as we may ever hope to have of the abnormal ossifications and bones as seen during the examination of anatomical material. The radiologist, however, encounters such ossifications under very different conditions and it is with the view of placing the problem of abnormal ossifications of the foot from the radiologist's point of view that I now place on record some of my more recent observations.

The accessory bones of the foot are of very special importance from a medico-legal point of view, and the frequency of the presence of some of them, as shown by radiography, is somewhat surprising. The accessory bones of the hand are, I believe, very much less common and of far less importance.

There are some ten or eleven of these accessory foot bones altogether[3], but some of them are not of much importance owing to their extreme rarity, and some which do not lend themselves to a definite display by X-rays.

The first one I depict is one of the most common (fig. 1)—it is known usually as the "tibiale externum," and it is situated on the posterior and external side of the tuberosity of the scaphoid. It has been demonstrated by radiography at the early age of three years, but those I have seen have been usually in adults. It is a definite skeletal bone; and as it is never enclosed in the tendon of the tibialis posticus it is not a sesamoid bone.

The presence of this bone may give rise to tarsalgia and even local manifestations of inflammation, and it may, radiographically, be mistaken in cases

[1] Abstract of a paper read at the Liverpoo[l] Medical Institute, Feb. 3rd, 1921.

[2] "Beiträge zur Kenntniss des menschlichen Extremitätenskelets," *Morphologische Arbeiten*, 1891–2, Bd I. pp. 1–120; pp. 517–760 (on sesamoids); 1894–5, Bd IV. pp. 347–570 (on special ossifications of hand); 1896, vol. VI. pp. 245–514 (on special and uncommon ossifications of foot). See also Dr M. Lupo, *La chirurgia degli organi di movimento*, 1920, vol. IV. p. 141 (abnormal ossifications of foot); *Biometrika*, 1921, vol. 13, p. 133 (sesamoids of knee).

[3] List in Quain's *Anatomy*, 1915: (1) Os trigonum; (2) os sustentaculum proprium; (3) calcaneus accessorius; (4) calcaneus secundarius; (5) ossiculum trochleae; (6) tibiale externum; (7) cuboides secundarium; (8) os intercuneiforme; (9) sesamum peronaeum; (10) os intermetatarsum; (11) os Vesalianum.

of injury for a fracture of the tuberosity of the scaphoid. To assist in making the exact diagnosis the other foot should always be examined, and in the large majority of cases it will be found to be also present in this other foot (figs. 1

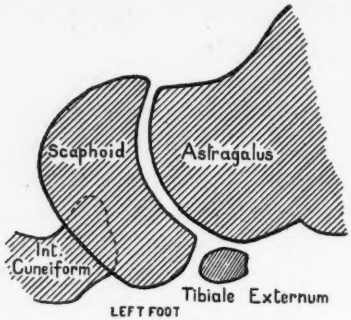

Fig. 1. Tibiale externum of left foot.

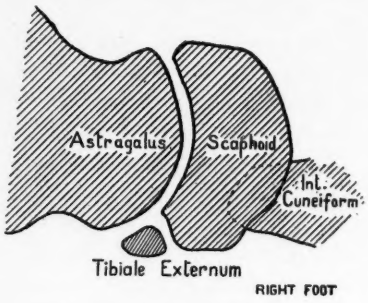

Fig. 2. Tibiale externum of right foot.

and 2). A similar condition in both feet would obviously put fracture practically out of court.

Further, in making a differential diagnosis, the appearance of the edges of the bones is valuable, as in cases of injury the edges of a fractured bone will almost certainly be irregular, whilst on the other hand the lines of both it and the adjacent scaphoid will be quite normal and well-defined when the condition is that of an accessory bone.

Before passing on to the consideration of some others of these definite bones, let me depict here some of the true sesamoid bones.

The first one is that usually known as the sesamoid bone in the tendon of the peroneus longus, and it was first described by Vesalius in 1555. It lies,

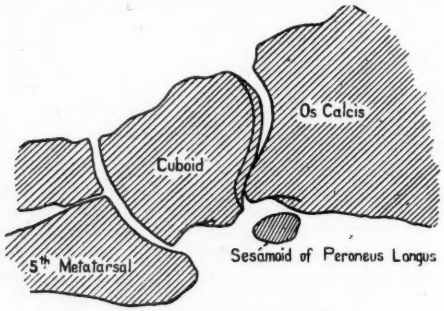

Fig. 3. Sesamoid on peroneus longus.

as is shown in the radiograph, posterior to the base of the 5th metatarsal and in close proximity to the edge of the cuboid.

Comparatively it is very common and varies very much in size and shape, and the fact that it may be present should be known when considering the

radiographical appearance in cases of injury. Apart from its situation, shape, clear cut edges and so on, a comparison with the other foot will almost invariably show a similar bone on the other side.

The two other prominent sesamoids of the foot are those beneath the distal end of the first metatarsal in the tendons of the flexor hallucis brevis.

These appear as somewhat oval shadows lying side by side. Developmentally, and by X-ray examination, it has been noticed that the inner one may be in two, three, or even (very rarely) in four separate bony pieces. It is somewhat

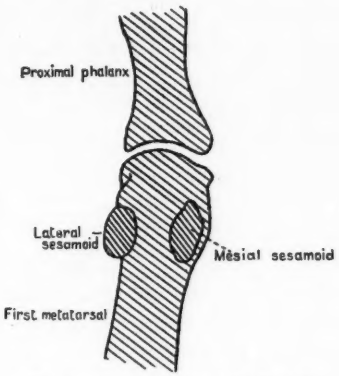

Fig. 4. Sesamoids of 1st (hallucial) metatarsal bone.

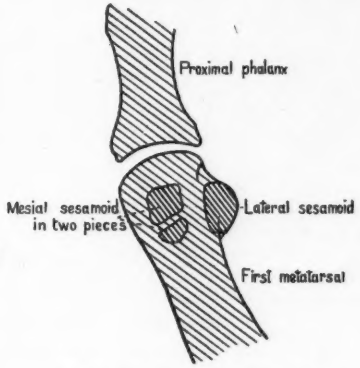

Fig. 5. Division of mesial hallucial sesamoid.

curious that this departure from the normal so rarely affects the outer sesamoid; even Dwight[1] had only once seen it in two pieces, and personally I do not ever remember seeing it so in a radiograph. One point to be specially noted is that when these bones are in two pieces the line of cleavage is always transverse to the length of the bone.

Many times such a bone, shown radiographically, has been described as fractured, more especially in those cases in which there is a history of a foot injury; in my experience this fracture must be a very rare occurrence, and most of the so-called fractures are really nothing of the kind. Seen on the radiograph the lines of separation of the two halves are very clearly defined and quite regular, the spacing being quite even. If a bone is cracked across one rarely sees radiographically such a straight and even line of fracture, associated with a definite regular space between the two halves. The great point, however, in differential diagnosis is the radiograph of the other foot, a symmetrical appearance, which is the rule, should negative fracture.

To return to the true accessory bones. In injuries about the ankle joint the os trigonum is of importance. Radiographically the shadows of the posterior part of the astragalus vary considerably according to (*a*) the shape

[1] Prof. Th. Dwight, "Variations in Bones of Hands and Feet," *Clinical Atlas.* 1907.

of the bone, which is variable, and (*b*) according to the exact angle in which the radiograph is taken. Normally the posterior part of the astragalus is

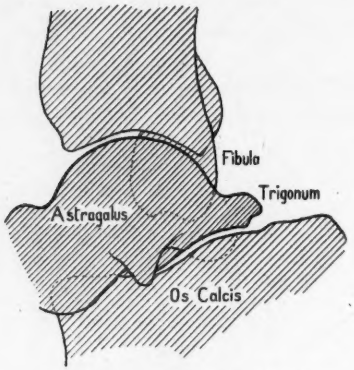

Fig. 6. Os trigonum fused with astragalus.

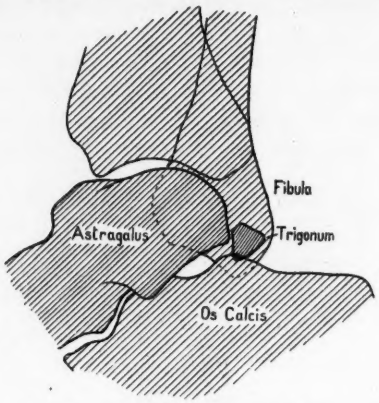

Fig. 7. Os trigonum separate from astragalus.

drawn out backwards into a projection, and in some radiographs, for instance in fig. 7, shows very prominently. Now the os trigonum when present is situated just at the back of the upper surface of the astragalus, and radiographically shows in such a position that it may simulate a fracture of this projecting piece of the bone. There is no doubt but that it is a distinct bone and Dwight has found it distinct in cartilage at birth. It is not known ever to give rise to any symptoms. Apart from the X-ray appearance already described as helping to distinguish a true bone from a fracture at the posterior end of the astragalus, the true bone is usually symmetrical and should be seen in the other foot.

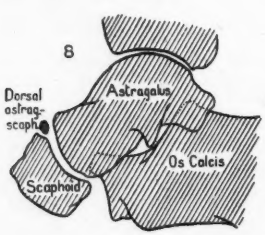

Fig. 8. Dorsal astragalo-scaphoid ossicle.

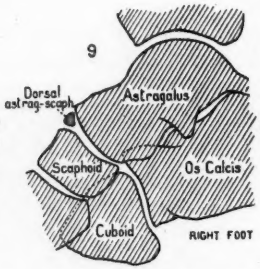

Fig. 9. Dorsal astragalo-scaphoid ossicle (right foot).

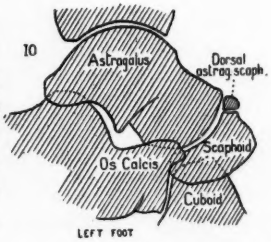

Fig. 10. Dorsal astragalo-scaphoid ossicle (left foot).

A further addition to our knowledge of these extra bones was made by Pirie in 1919 when he described a little ossicle, which he had met with in eight cases, lying between the upper surfaces of the astragalus and scaphoid. In

most of his cases again it was symmetrical and present in each foot. On referring his discovery to Professor Robinson of Edinburgh the latter said that he had never seen or heard of such a bone, but had suspected that it might exist as he had once seen an articular surface for such a bone on a scaphoid.

I have met with a few cases; its proper recognition is essential in view of injuries in this region, and also in view of the fact that certain painful conditions are not unfrequent in this part of the foot.

I next come to the most interesting of all these bones, namely the one known as the os Vesalianum, or the "bone of Vesalius." It lies at the base of the 5th metatarsal.

Referring to the description of this bone by Vesalius in the 1725 edition (of which there is a splendid copy in the library of the Liverpool Medical Institute) we find a picture—a beautiful drawing of the bones of the foot, and at the base of the 5th metatarsal and close to the cuboid is figured a small

Fig. 11. Tracing from Vesalius of the bone named after him by Pfitzner.

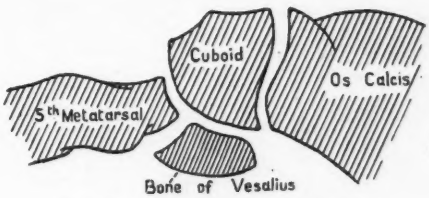

Fig. 12. Tracing from print given by Laquerrière and Drevon.

bone. Translated into English the description is: "A small bone, opposite to the outer side of the joint, and placed proximally to the little toe, and *probably articulating with the cuboid*[1]."

I have been in communication with Professor Keith[2] as regards this and other bone abnormalities and he writes me that "he considers that Vesalius describes really the sesamoid of the peroneus longus." There are other grounds for considering that this is probably the case as Dwight describes the bone of Vesalius (os Vesalianum) as the proximal and lateral part of the tuberosity of the 5th metatarsal, states that it is excessively rare, and that he has never seen it in the macerated foot of an adult. (The drawing in the book of Vesalius is that of an adult foot, and the position of the extra bone does not correspond with that of Dwight.) Dwight also mentions that Spronck has seen it at birth, and that he himself had seen it in a girl of 12 years of age. He also quotes

[1] This "probably articulating with the cuboid" is the key to the situation, as the peroneus tendon is in a groove in the cuboid at this spot and it is here that the sesamoid is found. Sometimes a bursa intravenes. This bone may be very large—up to 2 cm. in length.

[2] "Lately I have examined more closely Pfitzner's account of this bone and I fear I have misled Mr Thurstan Holland. An element, other than the peroneal sesamoid does occur at the base of the 5th metatarsal and in contact with the cuboid, but there is reason to doubt that this—which represents the os Vesalianum according to Pfitzner—can be reduced so as to become a mere epiphyseal plate on the base of the 5th metatarsal."—A. Keith.

Gruber as having seen a proximal epiphysis, not to be confounded with the os Vesalianum, distinct, in *an adult*[1].

There is also a paper by Laquerrière and Drevon in which are figured two cases, present in both feet. In one a very tiny piece of separate bone is seen exactly behind the tip of the base of the 5th metatarsal. This case is not of much importance; but the second shows a very large separate bone at the base of the metatarsal in both feet together with a metatarsal in which the usual tuberosity appears to be wanting. This is described as a true bone of Vesalius: on the other hand it looks like a complete separation of the tuberosity of each metatarsal, and in this case it would mean that the tuberosities were developed from separate centres and had not joined on. This case is an adult.

Lupo in his paper says "that the utmost confusion exists with regard to the os Vesalianum, and that he recognises a definite bone, and also an epiphysis at the base of the 5th metatarsal."

Again I have had his paper translated and in my opinion he merely adds confusion to confusion, as the only illustration he reproduces he describes as showing an undoubted accessory bone of Vesalius, and yet it is obviously

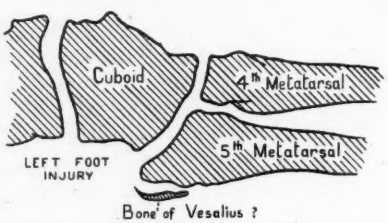

Fig. 13. Tracing from plate of left foot of boy aged 16 years.

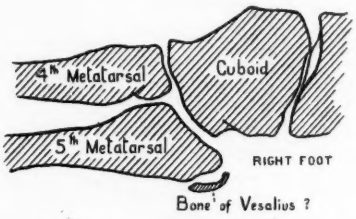

Fig. 14. Tracing from plate of right foot.

typical of what is really an epiphysis. This author also states that this bone is excessively rare (i.e. of course the one he pictures).

Dwight reproduces one radiograph only—that of the foot of a child, probably a girl, about 13 years of age. He describes it as an example of the bone of Vesalius. Again it is to my mind obvious that it is merely an epiphysis. I will show you later radiographs of my own which might have been the originals of both these cases as they are like them in all details.

During the past year I have seen six cases, and it was the first one of these which called my attention to this bone.

A radiograph was brought to me at the Royal Infirmary, Liverpool, one afternoon of the left foot of a boy of 16 years of age who had been run over by a motor, the wheel of which passed over the dorsum of the foot. Looking at this one sees a thin strip of bone lying outside the base of the 5th metatarsal.

[1] I have had made for me a translation of this paper of Gruber's but it appears to me to be somewhat involved, and I am not satisfied that he was actually describing such a separate bone in an adult.

What struck me was the regularity of this strip of bone, that everywhere it lay equidistant from the main bone, and that altogether from its appearance it did not look like a fracture. It then came to my memory that I had read somewhere something about a bone of Vesalius, and I asked for a radiograph of the other foot. The other foot was examined and showed the same strip of separated bone. A further examination of the injured foot showed that there was no pain or tenderness over the base of the 5th metatarsal, and it became quite clear that we were not dealing with a fracture, but with the so-called bone of Vesalius.

The condition is bilateral, is precisely the same in the two feet, and the appearances are exactly those one would expect if it were an epiphysis: also that injury is eliminated (*a*) by its presence in both feet, (*b*) by the fact of there being no pain or tenderness over it on the injured foot.

These radiographs are practically identical in appearance with the one shown by Lupo in his paper already referred to: and which he described as being the true bone of Vesalius as opposed to an epiphysis at the base of the 5th metatarsal.

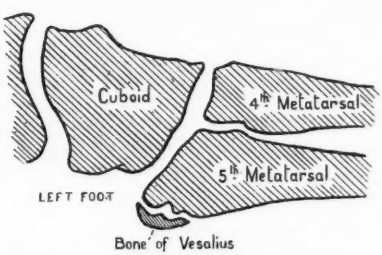

Fig. 15. Tracing of plate of left foot of boy $13\frac{9}{12}$ years.

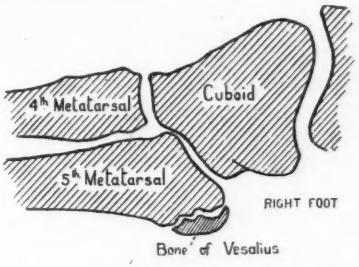

Fig. 16. Tracing of plate of right foot of boy $13\frac{9}{12}$ years.

One month later a boy of $13\frac{9}{12}$ years, again radiographed for a foot injury, showed similar appearances at the base of his 5th metatarsals. These radiographs reproduce identically the only one shown by Dwight, described by him as the bone of Vesalius.

Again you will notice the complete symmetry, and it is obvious that they must be epiphyseal—it is clear that unless this is the case, and taking them away altogether, then the bases of the metatarsals are quite abnormal, as if a piece of bone had been cut off from each.

A little more than one month later a boy of 16 years was radiographed for a foot injury, but it was the great toe which had been injured 18 months previously. Again a "bone of Vesalius" and obviously again an epiphysis. We failed to trace him to get a radiograph of his other foot, but in view of the other cases it appears to be pretty obvious. Four months later a girl, $13\frac{10}{12}$ years old, came with an injury to her left foot, and she proved to be a case of very great interest inasmuch as she showed definitely a small fracture of the base

of the metatarsal in addition to the bone of Vesalius, and it corresponded with a painful and tender area. Compare the two feet and the first, the uninjured, shows an obvious bone of Vesalius of the epiphyseal type; whilst the second shows the presence of the same bone in the injured foot and in addition a triangular chip torn from the proximal end of the 5th metatarsal.

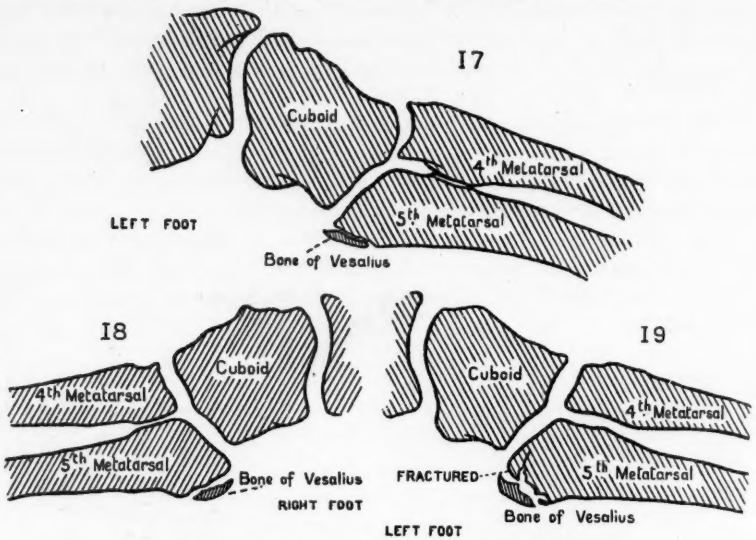

Fig. 17. Tracing from plate of left foot of boy aged 16 years.
Fig. 18. Tracing from plate of right foot of girl aged $13\frac{10}{12}$ years.
Fig. 19. Tracing from plate of left foot of girl aged $13\frac{10}{12}$ years.

Less than one month later a boy of $17\frac{1}{2}$ years came for examination, a waggon wheel having passed over his right foot one day previously. There was considerable swelling on the dorsum of the metatarsus and tenderness over the 1st metatarsal: whilst there was no tenderness over the 5th. A bone of Vesalius is again present, and this one is of interest inasmuch as it is ossifying from three centres—a condition not altogether unusual in similar epiphyses, for instance the one at the back of the os calcis. It was rather unfortunate that a careful search for this boy—even to the extent of putting the police upon his track—ended in a failure to find him. We should have had the other foot; however, I think it is clear that even without this, this is a definite example of still another bone of Vesalius.

My series was completed to date three weeks later when my friend Mr Prosper Marsden brought his little girl aged 12 years for examination of one foot, not for any injury. By radiographing both feet we found a fine example of this celebrated bone in each.

These are my six cases: and I think I am entitled to draw some conclusions from them.

Dwight states that it is excessively rare: he has never seen it in the macerated foot of any adult. He and Spronck have seen it at birth. The only X-ray Dwight reproduces is, in view of this series of mine, an obvious epiphysis.

Lupo, although most dogmatic as to the epiphysis and the true "bone of Vesalius" being two different things, produces no evidence of this; and the only X-ray he produces of his own—again in view of my series—is an obvious epiphysis, and this although (and this is important) he describes it as "clearly showing the real bone of Vesalius."

All my series, without an exception, suggest from the X-ray appearances that the true explanation is that they are epiphyses[1].

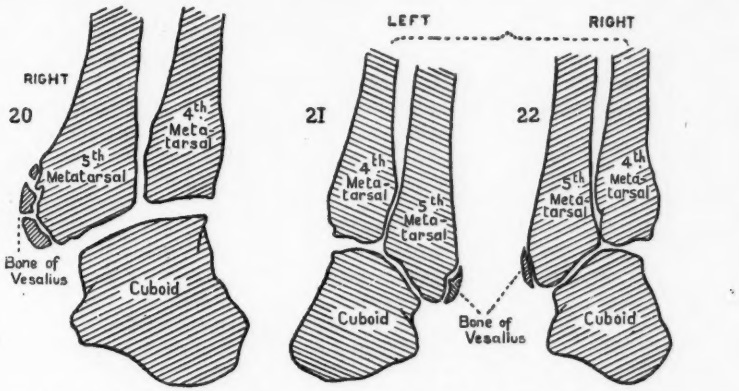

Fig. 20. Tracing of plate of right foot of boy 17½ years, three centres of ossification over tuberosity of 5th metatarsal.

Fig. 21. Tracing of plate of left foot of girl aged 12 years.

Fig. 22. Tracing of plate of right foot of girl aged 12 years.

I have never seen anything separate in any of the adult feet I have ever examined. All my cases are in young people—before the age of the complete formation of the skeleton. There is, as far as I know, no record of an adult radiograph showing such a separate bone, *with the base of the metatarsal at the same time well formed.*

I will therefore venture the opinion that the true "bone of Vesalius" does not exist as a distinct and separate bone. That Vesalius described the sesamoid of the peroneus longus and if any name is to be attached this is the "bone of Vesalius." That which is commonly described as the "bone of Vesalius" is in reality an epiphysis at the base of the 5th metatarsal which usually joins on or before adult life, but in one form may remain separate in the adult. This form—the very rare one—is seen in the case of Laquerrière, a diagram of

[1] "I agree with Mr Holland that the ossification represented is an epiphyseal one. Pfitzner however in six cases did find a separate element at the base of the 5th metatarsal bone as a separate cartilage and as a cartilage partly conjoined with the 5th metatarsal. Pfitzner was in error when he regarded this separate element and the epiphyseal plate as identical structures."—A. Keith.

which I have shown you, drawn from the radiograph of one of the two feet of his case. It is an example, which associated with the shape of the base of the 5th metatarsal, means that it is in fact the whole tuberosity, ossified from a separate centre, and remaining separate.

That all these examples of Dwight, Lupo, and myself—and others—are really an "epiphysis." Further I will also suggest that this epiphysis as shown by us is comparatively a common one, and that it is frequently present, but missed in the radiograph, owing to the position in which the foot is usually examined—the usual position being a direct one with the sole down on the plate. In our examination of the tarso-metatarsal region we adopted a position in which the inner side of the foot is on the plate whilst the outer is tilted upwards from the plate to an angle of about 15–20 degrees—a position for which I am indebted to my late assistant at the Royal Infirmary, Mr Woods. This brings the base of the 5th metatarsal with the epiphysis—if it is present—well into the field. I have tested this in some of my cases in which the epiphysis showed plainly. In this in the direct sole down position the epiphysis either did not show at all, or showed so slightly that it would have been overlooked without the tilted, semi-lateral view, as this epiphysis is on the under and outer side of the base of the 5th metatarsal bone.

There is a disease of the scaphoid bone of the foot which occurs in very young people and which was first described by Köhler of Wiesbaden in 1908 and is known as "Köhler's disease of the scaphoid." It is comparatively rare, less than 20 cases having been described in literature up to 1919, and it is entirely an X-ray discovery.

The symptomatology is that a young child is noticed to have some pain in his or her foot, and is limping. Examination discloses on the dorsum of the foot an area of tenderness, swelling, and possibly some redness, over the inner side of the tarsus. Usually I take it the cause would be put down as due to the rubbing of a boot. The foot is X-rayed and shows a remarkable condition. Whilst all the other bones show normal ossification, that of the scaphoid is quite abnormal. As compared (1) with the amount of ossification of the other bones there is an arrest of the process in the scaphoid, and (2) that area already ossified is abnormally opaque to the X-rays.

Whilst the X-ray appearances are quite typical, the exact pathology is at the present time uncertain. Tubercle, syphilis, defective ossification caused by fracture, trauma, or osteitis have all been put forward by one or other observer as possible explanations. Owing to the results of treatment the two former can I think be excluded. The exact cause is still a matter of doubt but I suggest that pressure or rubbing from foot gear causing a chronic irritation of the part may possibly have something to do with it. Be this as it may the result of treatment, or even in the absence of treatment, the symptoms disappear and the child becomes apparently quite well. Rest seems to be the only thing required—and this even for only a short period of time.

Two typical cases of this disease are shown in figs. 23 and 26, and I can

also show the radiological appearances at a later date when all symptoms had entirely disappeared.

The first is the foot of a girl of $3\frac{1}{2}$ years of age and it is typical. It will be seen that the ossification of the scaphoid is arrested and that the density to X-rays of the part ossified is great when compared with the rest of the tarsal

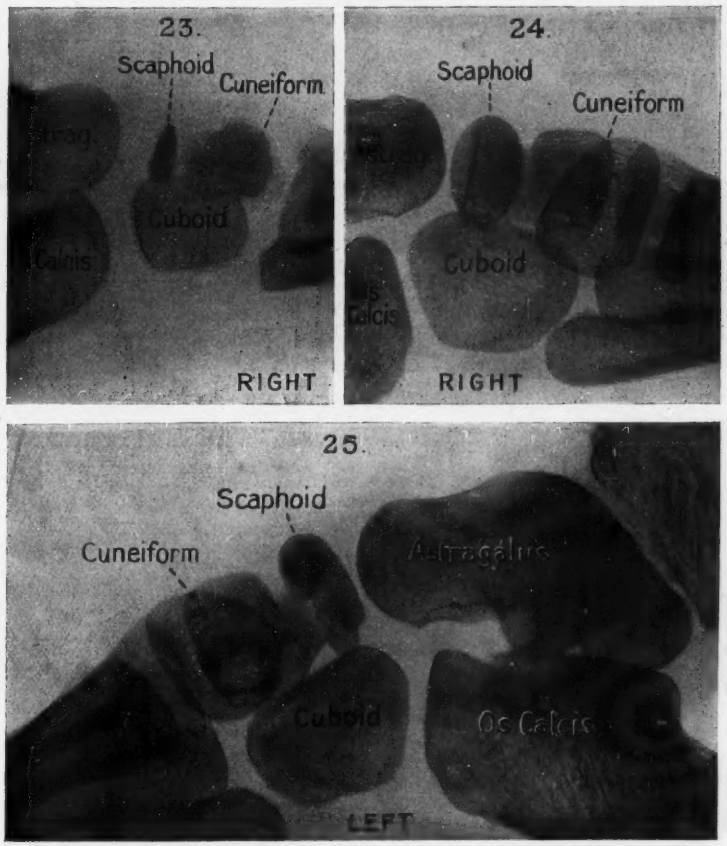

Fig. 23. X-ray plate of mid-tarsal region of right foot of girl aged $3\frac{1}{2}$ years.
Fig. 24. X-ray plate of mid-tarsal region of right foot of same girl aged $5\frac{1}{4}$ years.
Fig. 25. X-ray plate of mid-tarsal region of left foot of same girl aged $5\frac{3}{4}$ years.

bones. Only the one foot was radiographed in this case. Two years and three months later I re-examined the foot and also took a picture of the other foot. Now the scaphoid of the affected side, whilst showing that ossification generally has caught up to the normal, still shows an area of great density. At this time no symptoms of any kind were present.

In the other case—a boy 9 years of age—both feet were examined at the first and the contrast between the two scaphoids is obvious and again typical. Twenty months later, all symptoms having disappeared, the affected side is still slightly more opaque than the other, otherwise there is no difference.

Neither case had any special kind of treatment other than rest.

I now come to my last abnormality—a very rare one—probably the rarest of all those I have described—one affecting the patella.

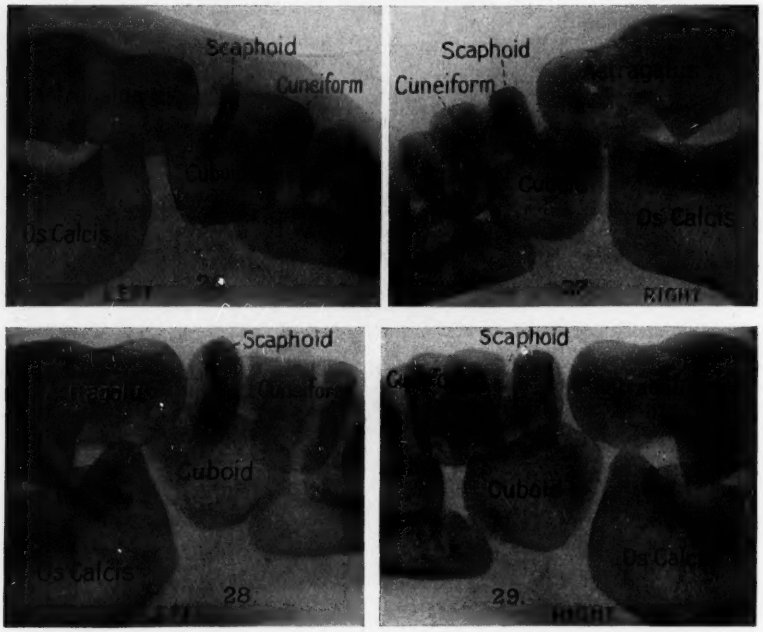

Fig. 26. X-ray plate of left foot of boy aged 9 years showing arrest in ossification of scaphoid.
Fig. 27. X-ray plate of right foot of boy aged 9 years showing normal ossification.
Fig. 28. Same foot as in fig. 26, twenty months later.
Fig. 29. Same foot as in fig. 27, twenty months later.

In radiographing one knee of a boy of 18 years of age who had rickets, knock-knee, inability to completely straighten the knee joint, etc., we found a curious condition of the patella (fig. 30). It was perfectly formed and ossified with the exception that at its upper and outer margin there was a completely separated piece of bone, much as if it had been fractured, but there was no history of any injury at any time.

It was known that a patella sometimes ossifies from two centres placed side by side, but these radiographic appearances do not suggest this as the explanation. I came to the conclusion that we had some quite abnormal

condition to deal with and had the other knee X-rayed (fig. 31). This showed a somewhat similar appearance in the same region, but the piece of bone was not entirely separate on this side but was joined on to the rest of the patella at its upper end.

We then decided that we had to deal with a condition of the patella in which there were separate centres of ossification at the upper and outer borders in the nature of epiphyses.

The literature is very small, but Mouchet in 1919 published a somewhat similar case and I reproduce drawings from his illustrations—these drawings being made for him from his radiographs (figs. 32 and 33). These show epiphyses

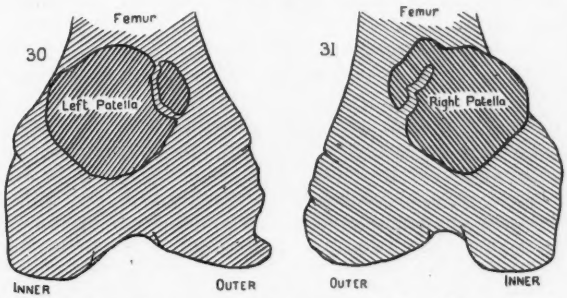

Fig. 30. Tracing from X-ray plate of left patella of a lad aged 18 years.
Fig. 31. Tracing from the right knee showing a corresponding anomaly of patella.

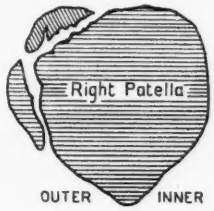

Fig. 32. Right patella in Mouchet's case.

Fig. 33. Left patella in Mouchet's case.

which he describes as being analogous to that seen at the posterior border of the os calcis and elsewhere. He refers also to three other writers, two of whom found a similar condition in adults when making autopsies, whilst the third had found it in the traumatic knees of adults.

As I wrote at the beginning of my paper these, and many similar, conditions have become of first class importance in view of two things: (1) the question of accidents and compensation, (2) the demonstration of these conditions by radiography.

In the earlier days of radiography even experts made many mistakes in interpretation owing to the fact that all this was new work which had to be

learnt gradually by experience. Even at the present time, when so much X-ray work is done by men without any special training, there is still a great chance that many of these rarities will pass unrecognised, or if they are recognised of being wrongly described. These must be my excuses for inflicting this paper upon you.

REFERENCES

Accessory Bones and Sesamoids of Feet

DWIGHT, THOMAS. "Variations of the bones of the Hands and Feet." *Clinical Atlas*, 1907.
QUAIN'S *Anatomy*, vol. IV. Part I. 1915.
PFITZNER. "Die Sesambeine des menschlichen Körpen." *Schwalbe's Morphologische Arbeiten*, Bd. I. 1892.
—— *Die Variation in Aufbau des Fussskelets, ibid.* Bd. VI. 1896.
SPRONCK. *Anat. Anzeiger*, Bd. II. 1887.
GRUBER. *Arch. für Anat. und Phys.* S. 48. 1875.
STIEDA. *Beiträge zur klin. Chirurgie*, 1904.
PIRIE. *Arch. Rad. and Electrology*, p. 93, 1919.
SCOTT. *Ibid.* p. 224, 1918.
VESALIUS. 1725 edition, p. 120.
LUPO. *La Chirurgia degli organi di movimento*, vol. IV. fasc. 2, 1920.
SHILLINGTON SCALES. *Arch. Rad. and Elect.* p. 83, 1918.
DENNIS. *Ibid.* p. 253, 1918.
JOHNSTON. "Epilunar and hypolunar ossicles, etc. etc." *Journ. of Anat. and Phys.* p. 59, 1906.
LAQUERRIÈRE and DREVON. "On the Vesalian bone." *Jour. Rad. and Elect.* (French), p. 395, 1916.

Köhler's Disease

O'BRIEN. *Bost. Med. and Surg. Journ.* p. 445, 1919.
KÖHLER. *Münch. Med. Woch.* vol. 55, II. p. 1923, 1908.
PFAHLER. *Surg. Gaz. Obst.* 625, 1913.
ROTCH and GEORGE. *Roentgen ray in Pedriatics*, 1910.
STUMME. *Fortschr. a. d. Geb. d. Roentgenstrahlen*, Hamburg, II. XVI. 342, 1910.
SCHULTZ. *Arch. für klinische Chir.* No. 2, p. 341, 1912.
WOHLAUER. *Zeit. für orth. Chir.* Bd. XXXI. II. 1913.
FASSETT. *Journ. A.M.A.* LXII. 1155, 1914.
HETZEL. *Amer. Journ. Orth. Surg.* XV. No. 3, 1917.
PREISER. *Berlin. klin. Woch.* XLVIII. 593, 1911.
HAENISCH. *Münch. Med. Woch.* vol. 55, II. No. 44, 2285.
BERTOLETTI. *Rad. Med. Turino*, II. 400, 1915.

Knee

MOUCHET. *Bull. et Mém. Soc. Anat. de Paris*, No. 11, p. 452, 1919.
—— *Bull. et Mém. Soc. de Chir.* I. XLV. No. 26, p. 1215.
GRUBER. *Virchow's Arch.* Bd. 94, p. 358, 1883.
JOACHMINSTAL. *Arch. für klin. Chir.* Bd. 67, 342, 1902.
REINBOLD. *Revue méd. de la Suisse romande*, No. 4, p. 653, 1917.

TACTILE LOCALISATION

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From a review of studies in sensation it is at once apparent that no perfectly satisfactory method for accurately testing tactile localisation has been evolved. Almost all the methods at present practiced only demonstrate very gross defects and fail to furnish measurable results. The tests most frequently used in the investigation of tactile localisation only show such a gross defect as failure to recognise correctly the segment of the digit upon which the pressure has been applied, a defect which in this research has been found to occur several times in apparently normal individuals.

In the course of an investigation of sensation, particularly with reference to the disturbances found in peripheral nerve injuries, it became necessary to decide upon some method which would supply more accurate information about the power of localisation and also provide measurable results. In this paper the most useful method and the results of the application of this method to normal individuals, so as to provide a normal standard for localisation, are described. Although the findings recorded in this work do provide a standard to be considered when testing pathological states, it is necessary to state that the provision of such a standard does not abolish the necessity for comparing the results of the same test upon normal and abnormal parts of the same patient.

METHOD

The method found to be most serviceable was a slight modification of that described as Henri's, but unfortunately it has not been possible for me to procure the original description of his method. The patient, having the part to be tested obscured from his vision, marked upon a life-sized diagram the position of the point he felt to be stimulated, whilst the observer recorded on another similar diagram the exact spot touched. The tactile pressure was made by a blunt instrument about ·2 cm. in diameter. After a sufficient number of points had been localised the two diagrams were superimposed and the two points recorded in each test were marked on one diagram, in different colours or by distinctive signs, and then the error in each case was measured off with a scale. From these measurements, if a sufficient number of points have been localised, the average error for the whole or individual parts—as each finger—may be determined. In the latter part of the investigation only one chart was used, the observer recording the exact point stimulated after the person examined had marked the point where he felt the stimulation, and this simpler procedure proved as successful and apparently as reliable as the more tedious original form.

Head(1) in a criticism of Henri's method points out the one great disadvantage of this test when he states that "many patients find a difficulty in translating an image of the part tested on to a diagram which can show only two planes of space"; but in practice I have only encountered this difficulty in the case of the thumb, and find the method perfectly reliable for testing the power of localisation on the fingers and palm of the hand, which are the parts where, for the purposes of clinical and scientific investigation, accurate information is most frequently and most urgently required.

Before commencing each examination instructions were given that on no account was the hand to be moved whilst the pressure was being applied, as of course such a procedure would render the results fallacious.

The examinations were all undertaken under similar conditions, with absolute freedom from any disturbance. The necessity for this and the importance of undivided attention was very marked in the recent examination of a patient. The examination was continued after a third person had come into the room and entered into conversation with me; up to the time of the entrance of the intruder the average error was ·5 cm., during the time the distraction occurred the error increased to considerably over a centimetre, and then returned to ·5 cm. again with the re-establishment of quietness.

The investigations into the normal power of localisation in the hand and fingers have been divided into three series.

SERIES I

In this series ten members of the medical profession provided the subjects for examination, eight of these were either surgical colleagues or members of the staff of the anatomical department, and all were familiar with the diagrams used for the charting of disturbances of sensation. This series was undertaken for two chief reasons. In the first place it was thought that any possible fallacy due to unfamiliarity with the diagrams would be reduced to a minimum, and secondly such a series would provide valuable information at the outset with regard to the introspective aspect of this form of sensation. All were right-handed and took great interest in the work, and proved excellent subjects for my purpose as they exhibited keen competition to show the best result. Most of the tests in this series were carried out by the two chart method so that no suggestion as to progress or type of errors could be extended to the person under examination until the completion of all the tests. The palmar and dorsal aspects of each hand and digits were explored in turn. Twelve stimulations on each surface were made, eight or nine of which were on the digits and the rest on the palm or dorsum of the hand. The digits and hand were not tested separately in this series or the next, because my original object was to arrive at a normal standard for comparison when testing patients suffering from injuries to such nerves as the median and ulnar. From the early results it became apparent that the error on the palmar and dorsal surfaces of the hand was considerably greater in most individuals than on

the digits, and therefore to permit comparisons the proportion of stimulations on the hand and digits has been maintained practically constant throughout series I and II.

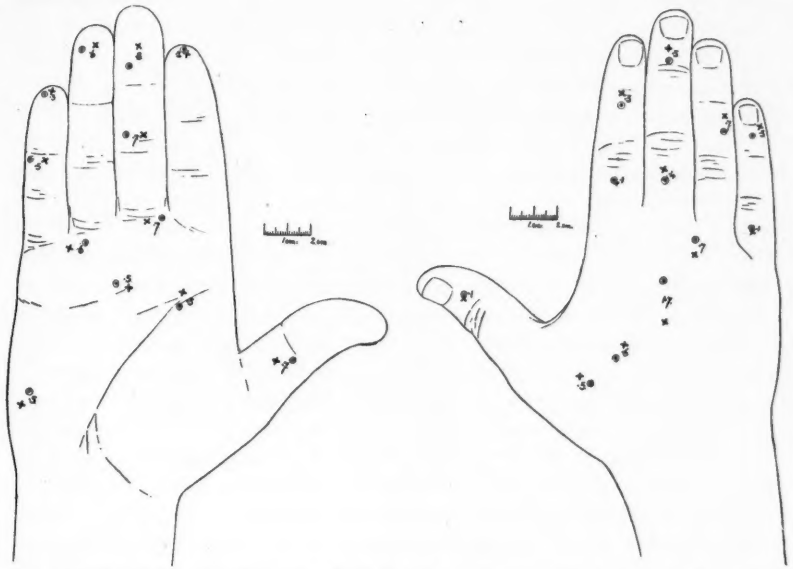

Fig. 1. Charts for the right hand of D. K. S. (Series I). × = precise point stimulated; ⊙ = point localised by D. K. S. The figures represent the error in each test measured in centimetres.

Table I.

	Right hand and fingers		Left hand and fingers		Errors proximal and distal
	Palmar surface	Dorsal surface	Palmar surface	Dorsal surface	
S. L. ...	·4 cm.	·5 cm.	·6 cm.	·6 cm.	Prox. 53 %
R. L. N.	·4	·5	·6	·5	Prox. 65
D. K. S.	·5	·5	·8	·8	Prox. 52
S. J. ...	·7	·6	·5	·6	Distal 66
H. P. ...	·8	·8	·8	1·0	Distal 63
W. H. W.	·4	·5	·5	·6	Distal 64
J. D. B.	·5	·4	·6	·4	Distal 53
C. E. B.	·6	·5	·6	·5	Prox. 63
E. A. L.	1·0	·9	·8	·5	Distal 71
G. J. ...	·6	·3	·4	·3	Prox. 61
Average	·6	·5	·6	·6	Distal 52

Table I shows the average errors in the four examinations of the ten subjects.

For the right palm and palmar surface of the digits the average error varied between ·4 cm. and 1·0 cm. (average for the ten = ·6 cm.), and the same sur-

face of the left hand and digits showed an average error varying between ·4 cm. and ·8 cm. (average for the ten = ·6 cm.). On the dorsal surface of the right hand and digits the average error varied between ·3 cm. and ·9 cm. (average for the ten = ·5 cm.), and on the left hand from ·3 cm. to 1·0 cm. (average for the ten = ·6 cm.). It is rather striking that on both the right and left hands in five the error was greater on the palmar surface. The explanation of this became quite clear as the work proceeded, since all agreed at the termination of the examination that they could localise the point much more readily when the pressure was applied over bone, and of course the phalanges and metacarpal bones are much more exposed on the dorsal than on the palmar surface. Tactile pressure over the metacarpal bones was usually more accurately localised than similar stimulation in an interosseous space. In the case of the digits alone greater accuracy of localisation on the dorsal surface was quite definitely found in nine out of the ten people examined in this series.

On the palmar surface the most accurate results were obtained when the point stimulated was upon one of the permanent creases, and several, who remarked upon the difficulty they experienced in localising a spot upon the palm, stated that they were much happier if the point was situated upon one of the creases. In six the power of localisation was definitely more exact on the right hand than on the left, in three the reverse was found, whereas in the other one there was no obvious difference in accuracy on the two sides.

E. A. L. localised one point on the wrong segment of the palmar surface of the left middle finger, and made a similar error on the dorsum of the right index finger. C. E. B. made a similar mistake on the palmar surface of the index and middle fingers. Three others localised on the wrong segment once, S. L. on the dorsal surface of the left little finger, H. P. on the dorsum of the left ring finger, and S. J. on the palmar surface of the left little finger. As will be seen from the last column of Table I the errors occurred in a proximal and distal direction in almost equal proportions.

SERIES II

In this series ten non-medical people were taken and only the palmar surfaces of the hands and digits of the two sides explored. The ten were composed of clerks, departmental stewards, porters and second year students. All were right-handed except H. G., who is ambidextrous. Reference to Table II shows that for the right palm and palmar surface of the digits the average error varied between ·4 cm. and 1·0 cm. (average for the ten = ·6 cm.), and on the left side it varied between ·4 cm. and 1·3 cm. (average for the ten = ·7 cm.). Except in the case of the left hand of R. M. P. (average 1·3 cm.) the results corresponded with those found in Series I. No explanation could be discovered for the gross errors found in R. M. P.'s left hand.

R. M. P. localised the point on the wrong segment of the finger three times on the right hand and four times on the left and repeated these mistakes when some of these points were restimulated (without R. M. P.'s knowledge that

Table II.

	Palmar surface Right hand and fingers	Palmar surface Left hand and fingers	Errors proximal and distal
A. F. C. D.	·5 cm.	·6 cm.	Prox. 52 %
H. H. ...	·7	·7	Prox. 55
H. G. ...	·7	·7	Distal 59
W. S. ...	1·0	·7	Distal 70
J. A. ...	·6	·7	Prox. 68
R. M. P....	·8	1·3	Distal 52
R. F. ...	·5	·5	Distal 76
N. P. ...	·5	·6	Prox. 59
M. C. ...	·5	·6	Prox. 55
P. G. ...	·4	·4	Distal 57
Average	·6	·7	Distal 52

the same spots were being again tested) at the end of the examination. W. S. localised the wrong segment of the finger once on the right hand and H. H. once on each hand. H. G. localised one point on the wrong finger of the left hand. In five the power of localisation was more accurate on the right hand and in two on the left, whereas in the other three there was no difference in the degree of accuracy on the two hands. As in the previous series errors were found in a proximal and distal direction in almost equal proportions. The close similarity in the results in Series I and II is rather remarkable, and shows that any error due to unfamiliarity with the charts, at any rate for the palmar surface of the hand and digits, must be very slight.

SERIES III

This series was undertaken to discover the average error for the individual fingers and to find out if there was usually any variation in the power of localisation in the different fingers; information on these points being of considerable importance in view of the recent additions to our knowledge made by Head (2) on patients suffering from injuries of the cerebral cortex. Two people were chosen from each of the two former groups and twelve stimulations (six on the palmar and six on the dorsal surface) were made on each finger. As far as possible two stimulations were made on both surfaces of each segment of each finger.

From these results, which are shown in Table III, it appears that the power of localisation does not vary to any obvious extent in the four fingers.

Table III.

	Index finger			Middle finger			Ring finger			Little finger		
	Both surfaces	Palmar surface	Dorsal surface	Both surfaces	Palmar surface	Dorsal surface	Both surfaces	Palmar surface	Dorsal surface	Both surfaces	Palmar surface	Dorsal surface
S. L. ...	·4 cm.	·5 cm.	·4 cm.	·5 cm.	·4 cm.	·5 cm.	·3 cm.	·3 cm.	·3 cm.	·4 cm.	·4 cm.	·4 cm.
S. J. ...	·6	·8	·4	·4	·4	·3	·4	·5	·4	·4	·4	·4
P. G. ...	·2	·3	·2	·3	·4	·2	·4	·5	·3	·3	·2	·3
A. F. C. D.	·4	·4	·3	·3	·4	·3	·4	·6	·2	·3	·4	·2
Average ...	·4	·5	·3	·4	·4	·3	·4	·5	·3	·3	·3	·3

Greater accuracy of localisation on the dorsal surface was found in all four on the index finger, in three on the middle and ring fingers, and in one on the little finger; in only two fingers (middle in S. L. and little in P. G.) out of the sixteen examined was there more exact localisation on the palmar surface. Only twice in the 192 tests was the point localised on the wrong segment of the finger.

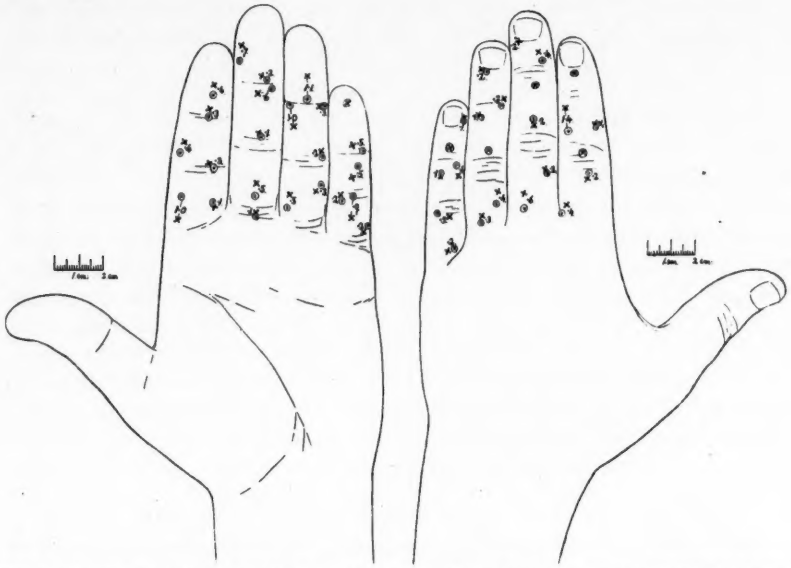

Fig. 2. Charts for localisation on fingers of A. F. C. D. (Series III). × = precise point stimulated; ⊙ = point localised by A. F. C. D.; ⊗ = correct localisation. The figures represent the error in each test measured in centimetres.

It was found that rather more difficulty was experienced in localising a point on the middle segment than on either the proximal or distal segments of the fingers.

Table IV.

	Index	Middle	Ring	Little
Right hand (normal) ...	·3 cm.	·5 cm.	·6 cm.	·5 cm.
Left hand	·6	1·3	2·1	1·2

The application of this method of measuring tactile localisation to pathological states will be considered as part of a subsequent paper, but for the purposes of comparison Table IV shows the results of testing the two hands in a patient who was suffering from a gunshot wound of the head in the right parietal region.

Some experiments were undertaken to investigate the power of localisation in the foot and toes by this method. Two practical difficulties were at once

encountered, first owing to the necessity of having to transpose in the case of the sole and plantar surface of the toes, and secondly on the dorsum owing to the difficulty, already referred to with regard to the thumb, experienced from a diagram only being able to show two planes of space. But these practical difficulties in themselves did not absolutely prohibit the application of a measurable test for localisation to the foot and toes, if the power of localisation in most normal individuals had been sufficiently well-developed in this region to warrant the application of a delicate test. It was rather astonishing to find that the normal people tested were unable with any degree of accuracy to state even which toe had been stimulated when the pressure was applied to the second, third and fourth toes.

On the great and little toes the point could be localised fairly accurately, an average error of about one centimetre being found.

In view of these results no further effort was made to estimate any standard for localisation in the toes, and from the above experiences it would seem that the foot and digits could not be used for any accurate investigation of localisation.

CONCLUSIONS

1. It is possible, at any rate for the hand and fingers, to obtain fairly accurate information about the power of localisation and to express the result of the tests numerically.

2. The average error for the hand and fingers appears to be about ·6 cm., but may vary between ·4 cm. and 1·0 cm.

3. The power of localisation is generally more accurate on the digits than on the hand.

4. Most people have less difficulty in localising tactile pressure when it is applied over bone than over such softer tissues as muscle, and this accounts for the greater accuracy of localisation on the dorsal than on the palmar surface of the fingers.

5. It was found that many individuals can localise a point stimulated more readily when it is applied on one of the permanent creases.

6. There is no obvious difference in the power of localisation in the different fingers of the same hand.

7. Localisation on the wrong segment of a finger may occasionally occur in apparently normal individuals who show no other disturbance of sensation, and consequently many of the tests at present in use, which only show gross errors, may lead to mistakes.

8. The foot and toes cannot be used for any accurate investigation of localisation.

REFERENCES

(1) Head, H. *Studies in Neurology*, I. 1920.
(2) —— "Sensation and the Cerebral Cortex." *Brain*, XLI. Pt II. 1918.

ON SESAMOID AND SUPERNUMERARY BONES OF THE LIMBS

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The study of the sesamoid structures forms an interesting chapter of anatomy. Owing to their size and frequent variations, they have attracted but little attention and are deemed undeserving of mention in many surgical text-books and anatomical treatises.

Nor have they been of great medico-legal interest, and for these various reasons these little bones have usually met with a neglect which has probably been increased by the absence of a systematised knowledge and correct classification.

I propose to give in this article a short account of the result of a radiological investigation and a summary of our present state of knowledge about these structures.

Hand

The sesamoid bones of the hand have been seen distributed as follows in 112 skiagrams (fig. 1). The percentages given in this diagram do not show a great variation from others found by other authors. The percentage (22·3) of the interphalangeal sesamoid of the pollex is much lower than Pfitzner's and Fawcett's figures. On the other hand the third and fourth digits metacarpo-phalangeal sesamoids appear, in my series, to be more frequent than other authors have indicated. It is remarkable to observe the great rarity of the interphalangeal sesamoids of the hand; as an X-rays structure, I could not find them in these 112 plates, and remember to have previously seen it once only in the joint between the primi and secundi phalanges of the index.

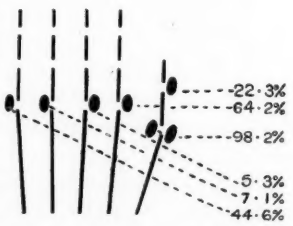

Fig. 1. Percentages of the hand sesamoids in my series.

The ages of the cases of this series were distributed as follows:

Between	15 and 25	years,	54 cases.
„	25 and 35	„	36 „
„	35 and 45	„	22 „
		Total	112 „

102 were males and 10 females.

The metacarpo-phalangeal sesamoids of the pollex were found missing in two cases. In one case it appeared as a single bone on the ulnar side, and in all the rest two bones were present. The interphalangeal sesamoids of the pollex appeared double in one single case.

The metacarpo-phalangeal sesamoids of the other digits appeared as a single formation. It is difficult to ascertain in a skiagram the side that these bones occupy. It appears that the radial side is more commonly seen to be the case of the index and medium fingers, and the ulnar that of the auricular and ring digits.

In one case I found the 3rd digit metacarpo-phalangeal sesamoid as a double structure, one bone being placed at the ulnar side of the metacarpal head and the other in the centre of the interval between the head of the metacarpal bone and base of the phalanx. In another case the index sesamoid appeared as a double structure.

It is curious to note that when the antero-posterior skiagram reveals the absence of the sesamoids of the fingers, the lateral plate will show them to be

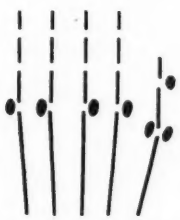

Fig. 2. Maximum number of sesamoids seen in one skiagram.

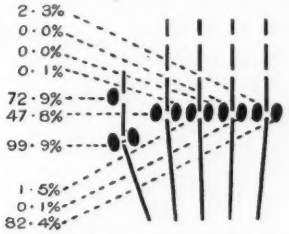

Fig. 3. Percentages of the hand sesamoids in Pfitzner's series.

either too small or the metacarpal heads will reveal an abnormal ventral cornual like projection. This interesting projection seems to take the place of the sesamoid.

The more numerous sesamoids seen in one skiagram in this series were distributed as shown in fig. 2.

In none of the cases was I able to find any evidence of bipartition of the pollex sesamoids.

It is noteworthy how disuse seems to affect the sesamoids of the hand, which reveal the same increase of transparency as the rest of the skeleton. Bony disease, such as rheumatoid arthritis, appears to affect these little bones as well.

Pfitzner in his dissections of the hand found the percentages shown in fig. 3, which are of exceptional importance owing to the considerable number of cases examined.

Fawcett, Stieda, Skillern and Retterer cases are of interest owing to the great variety and irregularity of distribution of the sesamoids. Retterer has dissected the hands of a man and found five bony and fourteen fibro-cartila-

ginous and vesiculo-fibrous palmar sesamoids on the right, and three bony and sixteen fibro-cartilaginous and vesiculo-fibrous on the left. In both hands there were fourteen fibrous dorsal sesamoids.

The pollex sesamoids more commonly, and rarely the others, are said to show two or more centres of ossification.

The centre of the sesamoids may be osseous, and the periphery fibro-cartilaginous. They may be larger in one hand, and appear as a bony formation in one side and a fibro-cartilaginous nucleus in the opposite.

Foot

The distribution of the sesamoid bones in 100 skiagrams of feet was as shown by the following percentages (fig. 4). These figures agree, on the whole, with the percentages found by other authors. The metatarso-phalangeal sesamoids form a constant feature of the skeleton of the human foot. The metatarso-phalangeal sesamoid of the 5th toe is the next in importance in this series. It was very difficult to determine whether it was a tibial or a

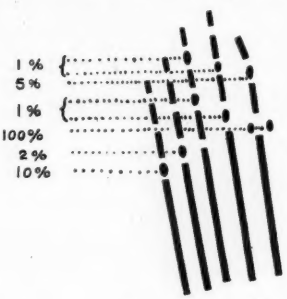

Fig. 4

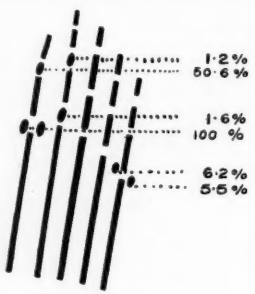

Fig. 5

Fig. 6

Fig. 4. Percentages of the foot sesamoids in my series.
Fig. 5. Percentages of the foot sesamoids in Pfitzner's series.
Fig. 6. Maximum number of sesamoids seen in one skiagram.

fibular formation, as it very often appeared directly opposite the centre of the head of the metatarsal.

The age distribution of these cases was as follows:

Between	15 and 25	years,	46 cases.
,,	25 and 35	,,	29 ,,
,,	35 and 45	,,	25 ,,
		Total	100 ,,

91 being males and 9 females.

The interphalangeal sesamoid of the hallux is very rarely seen in this series, compared with higher figures found by other writers. The great irregularity in the distribution of the more uncommon sesamoids seen in the series is worthy of note. They show more variety of distribution than is the case in

the hand. The maximum number of sesamoids found in a single case of the series is shown in fig. 6.

Pfitzner gave the percentages of the commoner podal sesamoids shown in fig. 5. It is to be noted that his figure of the frequency of the two sesamoids of the metatarso-phalangeal of the 5th toe is almost identical with the percentage of my series; and, on the other hand, the interphalangeal sesamoid of the hallux appears to be 45 per cent. commoner than in the skiagrams examined by me.

Stieda describes three skiagrams of feet which show a great variety of distribution of the sesamoids.

From what has been said previously, it is clear that the metatarso-phalangeal sesamoids of the hallux are the most important and constant in the foot.

The tibial sesamoid of the hallux appears to be more commonly the seat of normal anatomical alterations, a fact of great importance in dealing with the traumatology of these bones. In four cases the tibial sesamoid appeared divided as in fig. 7. This shows a very irregular distribution of the line of

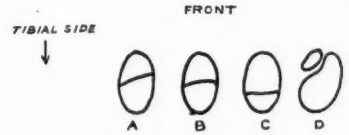

Fig. 7. Four cases of congenital division of the tibial sesamoid of the hallux. Cases *A*, *B*, *C* of transverse, and *D* of antero-posterior bipartition.

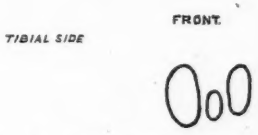

Fig. 8. A case of supernumerary sesamoid of the hallux. It differs from Fig. 7 *D* because the larger fragments show an outline without concavity.

division, and it should be mentioned that there was neither evidence nor history of fracture in any of these cases.

In one case (fig. 8) a third small sesamoid was present between the two constant ones, similar to a case described by Gillette.

In one case there was a fracture dislocation of the peroneal sesamoid of the hallux. The sizes of the metatarso-phalangeal sesamoids vary in both feet, and several times it was possible to detect such differences in our series. On the other hand any alteration in the alignment of the phalanx and metatarsal bones upsets the position of these structures. A marked valgoid position of the toe is always followed by a lateral displacement of the peroneal sesamoid towards the outer side.

Some of these data are confirmed by Geist, Gillette, Malgaigne, Momburg, Nesbitt, Pfitzner, Scott and Stieda findings.

Carpus

The carpal series very rarely displays any anomaly to be seen radiographically. In 100 skiagrams of the wrist, in one case there was a small dorsal bony formation at the wrist opposite the semilunar. This nodule was of the

size of a radial metacarpo-phalangeal sesamoid and was clearly seen in the lateral view. It is not clear whether it was a capsular formation, a radialis brevior sesamoid or the "epilunatum" (fig. 9 (1)). The fusiform and the uncinate process show very marked differences in size; and the projected surface of the latter in the antero-posterior view forms, in some cases, a well-marked radiographic detail. I found no evidence of "os hamuli" or of secondary pisiform being present.

In one case there was a small, bony nodule on the flexor surface and opposite the base of the first metacarpal, which may have been the "pretrapezium" (fig. 9 (2)).

In one case there was a small bone, corresponding to the secondary "os triquetrum" or the "ulnare antebrachii" (fig. 9 (3)), below the ulnar styloid process. In another case I met with a possible bipartition of the navicular (fig. 9 (4)), as I could not find any history of trauma.

Fig. 9. Diagram showing the distribution of the carpal anomalies seen in this series: (1) epilunatum, 1 %; (2) pretrapezium, 1 %; (3) ulnare antebrachii or triquetrium secundarium, 1 %; (4) (?) naviculare bipartitum, 1 %.

There was no evidence in any skiagram of any anomaly of the metacarpal bases.

All the cases referred to above were unilateral.

Tarsus

The tarsal series shows frequent and curious bony formations. A clear knowledge of these bones seems to be of some practical importance, as they occur with considerable frequency. In 100 skiagrams of the tarsus 21 abnormal bony formations were found as follows:

Os trigonum (intermedium) (fig. 10 (1)). It was present in seven skiagrams, in one being of very large size, and the rest of medium size. They were all single, except in one case in which the bone appeared to have been fractured by a piece of shrapnel. It is sometimes very difficult to state whether the bone is quite a separate and independent piece in the skiagram. The os trigonum was described by Rosenmüller in 1804, and found by Bardeleben in the embryo as a cartilaginous nucleus. It may have one, two or more nuclei of ossification. Keith says that it represents the semilunar. Eight per cent. has been the figure found by other authors.

Os peroneale (accessory cuboid, sesamum peroneum) (fig. 10 (2)). It was found in five plates. In one case it was bilateral. In all the cases it appeared as a small single bony formation. Sometimes it is placed slightly behind the cuboid ridge, which appears to be due to the posterior part of the os peroneale becoming ossified earlier. This bone is cartilaginous in children and later

becomes fibro-cartilaginous and osseous. Heavy work appears to precipitate such an alteration. I had an opportunity of confirming Retterer's findings. It may be said that the upper portion of the structure is cartilaginous, the lowermost tendinous and the intervening layer osseous. The os peroneale is developed in the peroneus longus tendon, and is the representative of the bony piece found at the angulated portion of the tendon Achilles of the frog. An analogous structure, seen in the long plantar of the rabbit and dog, which in these animals glides over the os calcis, has an identical phylogenetic significance (Retterer). It was first described by Vesale in 1555. It was found in 7, 8 and 10 per cent. of cases respectively by Geist, Pfitzner and Dwight.

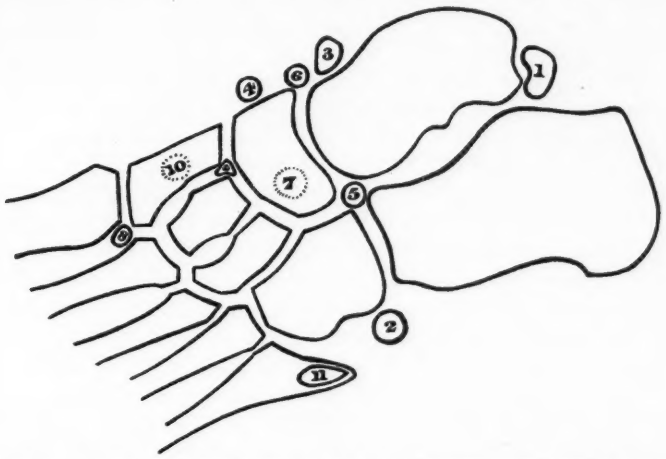

Fig. 10. Diagram showing the distribution of the tarsal supernumerary bones and sesamoids: (1) os trigonum, seen in 7 % of cases; (2) os peroneale, seen in 5 % of cases; (3) trochlear talar process, seen in 5 % of cases; (4) os tibiale, seen in 2 % of cases; (5) secondary os calcis, seen in 1 % of cases; (6) supra navicular (inter talo-scaphoid), seen in 1 % of cases; (7) secondary cuboid; (8) intermetatarseum; (9) intercuneiform; (10) division of first cuneiform; (11) os vesalii. The last five were not seen. This diagram also shows that the majority of the tarsal supernumerary bones are seen around the navicular.

Trochlear process of talus (fig. 10 (3)). This is a small bony formation found in the dorsum of the head and neck of the talus. It was seen in 5 per cent. of our cases. In one plate it was a very well-marked bony spicule and was present in both feet. The patient, a man 24 years old, only complained of pain while walking and due to a corn in the sole of the foot. He could wear boots. The other four cases were intermediate stages of development of the trochlear talar process. The X-ray appearance of this formation, well seen in the lateral view, does not resemble an exostosis, and it was not possible to find evidence of disease in any other part of the skiagrams.

Os tibiale externum (fig. 10 (4)). It was seen in 2 per cent. of the cases of this series. It forms a very interesting feature of the skeleton of the tarsus.

This bone has a cartilaginous nucleus in the second month embryo, and corresponds to the tubercle of the scaphoid common in some mammals. I found this bone well represented in the tarsal range of the sea-lion. It is found sometimes divided as if by a fracture. It is said it may be one of the causes of painful foot, and that it represents either the first cuneiform or a traumatic division of the navicular centre of ossification. Lupo brings forward the debated view which regards the scaphoid as resulting from the fusion of the tibiale externum, navicular and accessory scaphoid centres. The cases referred to in my series were men of 27 and 31 years of age. In one case the presence of the os tibiale was associated with a sesamoid of the metatarso-phalangeal joint of the 5th toe, and with division of the tibial metatarso-phalangeal sesamoid of the hallux. The pathology of the so-called Köhler's tarsalgia will be more clearly understood when a better understanding is reached of the morphology and ossification of the interesting human scaphoid.

Secondary os calcis (fig. 10 (5)). This little structure is to be found between the os calcis, cuboid and talus. It was seen as a small nucleus in one case only. It was found in a man of 32 years of age and it was associated with a vestige of supra-trochlear process of the talus, interphalangeal sesamoid of the hallux, and metatarso-phalangeal sesamoid of the 2nd and 5th toe. The secondary os calcis must not be mistaken for a *secondary cuboid* (fig. 10 (7)), which was not seen in any case of my series, and it is very seldom seen by means of X-rays. When present it is situated below the scaphoid which may show a connection with it. The secondary cuboid is still a debated anatomical entity.

In one case I was able to find a small independent bony formation between the talus and scaphoid (fig. 10 (6)); it was well seen in the lateral external skiagram on the dorsum of the foot. I cannot state whether this little bone was a sesamoid in a tendon or in the talo-navicular capsule.

Intermetatarseum (fig. 10 (8)). This bone is placed between the bases of the 1st and 2nd metatarsal bones, in the intermetatarsal cleft. It is said to represent a real metatarsal, and it has been found better developed in polydactylic cases. I was not able to see it among any of the skiagrams of the series and in seven special plates of polydactylia. I venture to suggest that this bone is identical with the so-called sesamoid described by Stieda. The intermetatarseum has been seen by Pfitzner and Dwight in 10 per cent. of cases.

Intercuneiform (fig. 10 (9)). Is to be found between the 1st and 2nd cuneiforms and the scaphoid.

Division of first cuneiform (fig. 10 (10)). This is an extra bony piece found in the plantar surface of the cuneiform.

Os vesalii (fig. 10 (11)). This appears, as in the hand, as a division of the base of the 5th metatarsal. Some authors claim it to be an epiphyseal irregularity; others maintain that this rare structure is a fracture of the metatarsal base.

Peroneal tubercle. It was described in one case by Pfitzner as an indepenent structure.

The *infra-tibial*, mentioned by Lupo, is to be found occasionally beneath the internal malleolus.

The last six of the varieties of tarsal formations described above have not been met with in this series, and usually they can very rarely be identified by means of X-rays.

Upper Limb

Small bones are in some rare cases to be seen in the *upper limb*.

Thus the *bicipital tendon* showed a small bony formation opposite the radial tuberosity in one case. This bone was of the size of a small metacarpo-phalangeal sesamoid. I have already referred to a sesamoid possibly developed in the *radialis brevior* tendon, opposite the wrist.

The much debated *tricipital sesamoids* and the *supinator brevis* described by Macalister were not seen in any of the 80 plates I have examined.

Lower Limb

In the lower limb the outer head of the *gastrocnemius* showed a sesamoid behind the femoral condyle in one plate out of 50. This was not very large, and radiographically it is noteworthy the great variety of sizes that this small bone exhibits. The internal gastrocnemius and the popliteus sesamoids are very rarely seen. The last named appears to be common in felids and the orang. The gastrocnemii sesamoids are well illustrated in a dried femur of "cynocephalus anubis" of the osteologic collection of the Royal College of Surgeons.

The psoas magnus, gluteus maximus, gracilis, long plantar claimed sesamoids have not been seen by me in any skiagram yet.

The patella forms another subject of much interest. In 100 consecutive plates of the knee I have not been able to find any "patella bipartita." This curiosity so well defined by Mouchet, Moreau and others requires a more prolonged study of this subject. The bilaterality of the anomaly does not appear to my mind to exclude the possibility of a traumatic origin of this curious condition. It is remarkable that the patella, though the largest sesamoid, very rarely shows any anomalies of ossification. The best position in which to detect patellar deformities and injuries by means of the X-rays is the antero-posterior with the knee and thigh flexed to 30 or 40 degrees and oblique exposure from behind. The thigh should be flexed as well as the leg. This position widens the tibio-femoral space and allows the lower portion of the patella to be seen directly in that interval.

Some points on Morphology

The morphological information regarding these structures is unfortunately still very inconclusive and lacking in precision.

The variations which these bones exhibit in shape and size in the mammalian series are well illustrated in the excellent osteologic collection of the Royal College of Surgeons of England.

The skeletons of the grizzly bear—*Ursus horribilis*—the deer hound, koodoo, elk, cervus show the distribution of these bones in the hands and feet, and the depth of the grooves in which they play. The same point is well shown in the limbs of the *Rhinoceros unicornis*, Sumatran rhinoceros, and hippopotamus.

The race horse Orlando of aristocratic and regal tradition, and the plebeian Spanish horse near it, display very little difference as regards the structure of their sesamoids, and this notwithstanding the turf career of agility and alacrity of the former, in marked contrast with the leisurely contemplative life probably led by the latter.

The skeletons of the *Bos Taurus*, *Tapirus indicus*, giraffe and elephant show the sesamoids in the four limbs, and in the latter animal one is struck by the size of its patella. The dried hand and feet skeletons of the armadillo, ant eater, badger, kangaroo, hedgehog, rabbit, hare and dog show an interesting degree of evolution of the sesamoids.

Specimen H. 26. 1 shows the hemisection of a horse's foot in which one of the upper sesamoids has been cut in a vertical direction. Here it can be seen how the tendon is attached, and contrary to what has been maintained by some authorities, the fibres of the tendon seem to run in the posterior surface of the sesamoid, while a few appear to end in this bone. The articular surface is smooth and plays in the groove of the phalanx and head of the metacarpal. Its appearance is exactly like that of the rest of the joint surface.

In making this rapid survey of the sesamoids of animals differing so greatly in size, weight and habits one is surprised to find that these bones do not appear to be related to the size of these skeletons in any definite proportion. In fact one may extend the dictum of Aeby by saying that the habits and size of a mammal seem to have no influence on the anatomical characters of their sesamoids.

In all, however, one fact is constant: they all seem to enlarge the articular surface of the joint, and in all they run in a well-formed groove. These grooves are subdivided by a central ridge similar to that seen in the head of the 1st human metatarsal, for instance.

Retterer recently studied these bones in the lion and cat, and states that, as in the dog, these animals have metacarpo- and metatarso-phalangeal and primi-secundii-phalangeal dorsal sesamoids. They are capsular thickenings, and are not ossified but fibro-cartilaginous.

Classification

The etymology of the word sesamoid shows how untrue is the exact up-to-date meaning of the word. It is rather inconsistent to compare bones of the size of a patella on the one hand, and the almost microscopical nodules of the articular phalangeal capsules on the other hand, to the grains of sesame of Galen. If size alone is to be the basis of classification the small supernumerary bones of the skeleton would be included in this class notwithstanding their recognised anatomical ancestry.

Cruveilhier (1881) proposes to confine the name sesamoid to the patella.

Gillette classified the sesamoids into *peri-articular* and *intratendinous*. Pfitzner divided them into *real* and *false*. The former are those that cannot be grouped in any other known category of bones. The false are bony or calcareous new formations of pathological origin, supernumerary bones of the carpal or tarsal range, little bony pieces in or in close contact with some tendons.

Poirier has grouped the sesamoids into *constant* and *inconstant*. The former being only the metacarpo- and metatarso-phalangeal sesamoids of the pollex and hallux. The latter being any others. Retterer proposes a histological classification, dividing these structures into four different groups: (1) *Fibrous*, (2) *Vesiculo-fibrous*, (3) *Cartilaginous*, and (4) *Osseous*.

To my mind, if Nesbitt and Thilenius' deductions are accepted, there is only the phylogenetic factor as a basis of classification. Then, whether these structures be bony or fibrous, they are all of the same nature as Retterer's claims. Evidently any accidental pathological finding has to be excluded. Many details, however, in the science of phylogeny need to be filled in before an accurate classification of the sesamoid structures can be achieved. Such is the reason that forces me to divide them into *supernumerary bones* and *sesamoids*. The former having a well-defined phylogenetic meaning, and the latter being those which have an unknown anatomical pedigree.

Anatomo-Physiology

It is difficult to give a reason for the existence of the sesamoid structures in the human body.

If function is accepted as the cause of the formation of these structures, as parts of anatomical systems, it becomes necessary to state what physiological duties they have to perform.

If, on the other hand, the phylogenetic theory is to be accepted, it still remains to find the reason for so many individual variations.

Again, it has been fully demonstrated that the sesamoid structures have an evolution resembling that of other bones. In fact, they present definite evolutionary stages, starting as a mesoblastic core and ending in some cases as real bony structures.

The sesamoid problem comprises two separate questions, as follows: (*a*) why should these structures appear; and, (*b*) when once formed, what are the functions that they have to fulfil? In fact the sesamoids are not an accidental formation. They are not due to a mere ossification in a tendon; they are real bones, having a definite cartilaginous nucleus—Nesbitt, Gillette, Thilenius.

Bradley expresses the opinion that these bones have a phylogenetic origin.

Monro stated that the causes of sesamoids are manifold. They are to be found where tendons and ligaments are firmest, muscular action strongest, and compression greatest.

In Gray's anatomy it is stated that the sesamoids have a phylogenetic

reason of existence; and that their functions probably are to modify pressure, to diminish friction, and occasionally to alter the direction of the pull of the muscle. Parsons suggests that "some traction epiphysis were once sesamoid bodies."

Wood-Jones thinks that the manual sesamoids are ossicles in the tendons of a fluctuating group of intrinsic muscles which produce flexion of the metacarpo-phalangeal joints.

On the other hand their functional importance in animals has been long recognised. Youatt gives in his book the following description of the sesamoid function in the horse: "in proportion as the pastern is oblique or slanting, two consequences will follow, less weight will be thrown on the pastern, and more on the sesamoid...and in that proportion concussion will be prevented."

Assuming for a moment that the phylogenetic theory is accepted, it remains to find the reason for the variations of the sesamoids. The two metacarpo-phalangeal sesamoids of the pollex are developed by the strong movements of opposition which will produce pressure in the palmar surface of the capsule. The metacarpo-phalangeal joints of the pollex, index and auricular appear to be the seat of maximum pressure when the hand grasps an object. The heads of the corresponding metacarpals even show alterations of shape due to the same pressure—Gillette, Retterer. In these three places one finds with comparative frequency the pollex, index and auricular sesamoids, as it was demonstrated.

The metatarso-phalangeal sesamoids of the hallux are a constant feature of the human foot. They appear to be placed at a point of maximum pressure and friction of the base of the anterior pillar of the internal arch of the foot. It is on this point that the strong flexor of the hallux plays, at an angle, in walking. The elevation of the body, in taking a step, is preceded by a strong metatarso-phalangeal and ankle extension. Whenever the line between the metatarsal and the phalanx of the hallux varies, as in abduction of the toe, the two sesamoids alter their position as well. In such movements the X-ray examination will reveal these structures displaced outwards, and the peroneal sesamoid appearing in the cleft between the 1st and 2nd metatarsals. Frazer says that the sesamoids of the hallux with the soft tissue covering are responsible for the plantar prominence of the ball of the toe.

The other sesamoids of the hands and feet never attain large dimensions, and are all extremely inconstant as far as ossification is concerned. They appear to be always present at the flexor and extensor surfaces of the capsules of all the joints but in a vestigial stage only.

The so-called articular sesamoids appear to enlarge the joint surface and to render the articular movements conformable to the condylarthrosis type of articulation. In fact, extension and flexion appear to be the dominating or sole types of motion exhibited.

Taking the pollex and hallux as instances, it will be found that more complex movements will take place at the carpo-metacarpal and tarso-metatarsal

articulations. In the case of the pollex, the trapezio-primi-metacarpal joint is an epiphiarthrosis, which supplements the mechanical deficiency of motion of the metacarpo-phalangeal articulation. The same can be said of the very elaborate reniform arthrosis of the primi cuneiform metatarsal.

On the other hand, it is noticeable that the sesamoids generally appear close to the seats of muscular insertion, and there are very few exceptions to this rule. The great majority of sesamoids are not only situated near a joint, but are always found in close contact with other bones.

The heads of the metacarpals appear to show, as it has already been said, by means of the lateral view of the X-rays a cornual-like projection, whenever the sesamoids of the corresponding joints fail to appear as independent structures.

Age seems to have a definite influence in sesamoid ossification. Sex in our experience does not appear to be of any significance.

Pressure, traction and friction alone are not the cause of the formation of sesamoids.

Pressure usually produces cartilaginous formations, or a curious adipose-like tissue, seen for instance in the Haversian formation of the hip.

Traction, by itself, brings the mesoblastic core to a line, and stretching orientates the cells in a direction parallel to the line of force, as in a tendon for instance.

Friction, on the other hand, places the cells, as it were, in an oblique or vertical direction to the gliding motion. This has been well shown by Retterer.

Pressure combined with the complex series of movements of circumduction, displayed by an enarthrosis, as in the hip or shoulder, appears to originate a further anatomical element. The interesting ligamentum teres of the hip, and the long head of the biceps at the shoulder, with the cartilaginous brim of the cotyloid surface, probably owe their kinetic origin to these forces.

If a condylarthrosis has to perform gliding movements, these seem to give rise to a special element, the intra-articular fibro-cartilages. This structure follows the antero-posterior movements of the joint by gliding in a similar direction.

If the gliding motion is combined, as in the knee with a rotatory movement, the menisci become cartilaginous or, in some mammals, bony.

It seems, therefore, that every articulation of the types of enarthrosis or condylarthrosis, requires the presence of intra- and peri-articular elements of a sesamoid nature, produced either by motion or its consequence.

Phylogeny and function combined appear to be the two causes of sesamoid formation and development. The former originates and plants, as it were, the seeds for their formation, and the latter, acting daily and with every movement, promotes the increase in size of these structures.

It is hardly possible to accept either of these theories separately, and the only obscurity remaining lies within the elastic boundaries indicated by the term phylogeny.

My thanks are due to the Council of the Royal College of Surgeons for free access to the material in their Museum.

NOTE. The traumatology of these bones will be given in the *Annals of Surgery*.

BIBLIOGRAPHY

AEBY. *Arch. für Anat. u. Phys.* p. 261, 1875.
BARNES. *New York Med. Journ.* vol. 102, p. 940, 1915.
BRADLEY. *Anat. Anzeiger*, vol. 28, p. 528, 1906.
DWIGHT *Anat. Anzeiger*, vol. XX. p. 465, 1902.
—— *A Clinical Atlas*, 1907.
FAWCETT. *Journ. of Anat. and Phys.* vol. XXXI. p. 157, 1897.
FRAZER. *The Anatomy of the Human Skeleton.* Lond. 1920.
GEIST. *Amer. Journ. of Orth. Surg.* vol. XII. p. 403, 1915.
GILLETTE. *Journ. d'Anat. et Phys.* vol. VIII. p. 506, 1872.
GRAY. *Anatomy*, 1920.
KEITH. *Human Embryology and Morphology.* Lond. 1913.
LUPO. *La chir. degli org. di mov.* vol. IV. p. 141, 1920.
MACALISTER. *Journ. of Anat. and Phys.* vol. III. p. 108, 1869.
MONRO. *Anat. of the bones.* Edin. 1726; *Collected Papers.* Edin. 1781.
MOMBURG. *Deut. Zeit. f. Chir.* vol. LXXXVI. p. 382, 1907.
MOREAU. *Presse méd.* p. 374, 1920.
NESBITT. *Human Anatomy.* Lond. 1736.
PARSONS. *Journ. of Anat. and Phys.* vol. XIII. p. 248, 1904.
PFITZNER. *Morphol. Arbeit.* vol. I. p. 1, 1892.
—— *Ibid.* vol. IV. p. 347, 1895.
—— *Ibid.* vol VI. p. 245, 1896.
—— *Zeit. f. Morph. u. Anthro.* vol. II. p. 77, 1900.
POIRIER. *Anatomie*, vol. I. 1899.
RETTERER. *Journ. d'Anatomie*, vol. XX. p. 467, 1884.
—— *Comp. rend. soc. biol.* vol. LXXI. p. 7, 1911.
—— *Ibid.* vol. LXXXI. pp. 353, 630, 829, 1918.
SCOTT. *Arch. of rad. and elect.* vol. XXIII. p. 224, 1918.
SKILLERN. *Ann. Surg.* vol. LXII. p. 297, 1915.
STIEDA. *Münch. med. Woch.* vol. LIII. p. 1954, 1906.
—— *Beit. z. Klin. Chir.* vol. XLII. p. 237, 1904.
THILENIUS. *Anat. Anzeiger*, vol. IX. p. 425, 1894.
—— *Morphol. Arbeit.* vol. V. pp. 309, 462, 1896.
WOOD-JONES. *Principles of Anatomy as seen in the Hand.* Lond. 1920.
YOUATT. *The Horse.* Lond. 1866.

THE AURICULO-VENTRICULAR BUNDLE IN MAMMALS

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THE Auriculo-Ventricular Bundle with its connections is best seen, both by the naked eye and microscopically, in the heart of Ungulates, and for this reason a description of the appearances in the sheep will first be given, to serve as a standard with which other hearts may be compared.

SHEEP AND OX—MACROSCOPIC FINDINGS

If the endocardium be stripped off the right side of the ventricular septum from the junction of the septal and infundibular cusps of the Tricuspid valve to the base of the Moderator Band (which in the sheep and ox is always present, passing from the lower and fore part of the septum to the base of the anterior papillary muscle), a white strand will be seen about ½–1½ millimetres in width according to the size of the heart. This is the Right Branch of the A.V. Bundle (fig. 1). It can be followed by dissection along the Moderator Band, but not easily further than this. Tracing it backwards by removing the cusps, the endocardium, and a thin layer of muscle from the auricular septum, a definite fusiform expansion is reached, which is the A.V. Bundle itself (fig. 1). Careful dissection will bring into view another deeper strand of similar pale tissue, directed towards the left side of the septum, and taking origin from the A.V. Bundle. This is the Left Branch of the Bundle (fig. 1). It is seen as a definite pale strand through the endocardium on the left side of the septum, in a line from the junction of the Right coronary and non-coronary cusps of the Aortic valve to the apex of the ventricle, first appearing ½–1 inch below the cusps. It does not reach the apex but divides into several strands, the largest of which crosses in a false chord to the base of the anterior papillary muscle; another strand passes similarly to the posterior papillary muscle, and a third may often be seen continuing down the septum towards the apex.

If the A.V. Bundle itself be traced backwards on the auricular septum, it will be found to diminish in size, and finally disappear as a definite tract a few millimetres in front of the orifice of the Coronary Sinus. It is overlaid by muscle and endocardium of the auricular septum, and deep to it is the fibrous tissue known as the central fibrous body, or in some hearts, the os cordis, because of the bone developed in this region. This prolongation back-

wards from the fusiform expansion of the Bundle is the A.V. Node. In the sheep it is not defined from the Bundle as seen by the naked eye, but in larger hearts, as the ox, the tract first narrows behind the Bundle and then expands again into the Node. The ramifications of the Right and Left Branches of the Bundle under the endocardium of the ventricles are too fine to be traced by ordinary dissection, but may be very strikingly demonstrated by injecting each Branch with Indian ink. This ink is better for the purpose than Prussian

Fig. 1. Heart of a Sheep, with most of the Right Auricle and Right Ventricle cut away. Black arrows in the venous orifices and Pulmonary Artery. The A.V. Bundle and its Right Branch dissected, seen against black papers. The Left Branch is shown for about one-eighth of an inch. A piece of the anterior wall of the Right Ventricle is left hanging from the Moderator Band. ($\times \frac{2}{3}$ nat. size.)

blue, which does not photograph so well, and is apt to wash out of the tissues as they are prepared for paraffin sections. The best injection was obtained in the heart of an ox, which was well washed while quite fresh in running water for several hours, then opened and left on a dish for 3 days, covered by a glass shade which admitted plenty of air. The left ventricle was opened to be viewed from the front; the right ventricle was cut so as to be viewed when open from behind; these incisions allow of the best access for injection and the most complete view of each ventricle.

With very little pressure from the 5 c.c. syringe the ink ran readily into a network covering the bulk of the interior of both ventricles, reaching to the base of the valves and the apex of each cavity. Much more of the network appeared on the left side of the septum than on the right. Attempts to inject each Branch upwards into the Bundle and Node were not successful, no ink reaching these parts, as shown by later dissection. No ink ever flowed to the endocardium of the auricles or to the epicardium of any part of the heart.

Sheep and Ox—Microscopic Findings

A.V. Bundle and Branches

The minute structure of the Bundle and of the Right and Left Branches and their ramifications is similar in almost every detail. For convenience of preparing sections and studying these details, the Moderator Band is most useful, and the description of the Right Branch as it courses along this Band, or "true" chord, will serve as the type of Purkinje tissue throughout the ungulate heart. In transverse sections of the Moderator Band (fig. 2) the Right Branch of the Bundle is readily distinguished as an oval or circular mass of muscle, staining much less deeply with eosin than the ordinary muscle, and well marked off from the latter by a sheath of connective tissue. What appear to be the individual fibres of Purkinje tissue are very much larger than the fibres of the ordinary myocardium. They are apparently divided into compartments, three to six in number, by ill-defined dots taking the eosin tint more deeply than the main cytoplasm; these dots also often form a fringe for each Purkinje fibre (fig. 3). One or two rounded nuclei surrounded by granules may occupy a comparatively clear space in one or more compartments of each fibre.

A longitudinal section through the Purkinje tissue makes it very clear that the dots seen in a transverse section are simply the cross sections of fibrils which course along the Purkinje fibres (fig. 4). These fibrils are cross striated, just as are those of an ordinary myocardial fibre, but they by no means fill the Purkinje fibre as they do the ordinary fibre, being usually seen only at their periphery, and running obliquely, or almost transversely across them. It is obvious that if the Purkinje fibre were packed with fibrils, each of which takes the eosin stain deeply, the whole fibre would not appear pale when contrasted with the ordinary heart muscle similarly stained. It is the differentiated part of the protoplasm, the fibril, which takes the eosin tint deeply. The fibres of the Purkinje type branch and anastomose just as do those of the ordinary muscle, forming a syncytium, but one Purkinje fibre is 10–20 times the length of an ordinary fibre, and in cross section may be 50–100 times the area of an ordinary fibre, a single one of its compartments being perhaps 10 times the diameter of a myocardial fibre.

Connective tissue everywhere forms a sheath, not only for the whole tract of the Right Branch of the Bundle, but for each Purkinje fibre (fig. 3); it is this which gives the naked eye pallor to the Branch, which makes its dissection

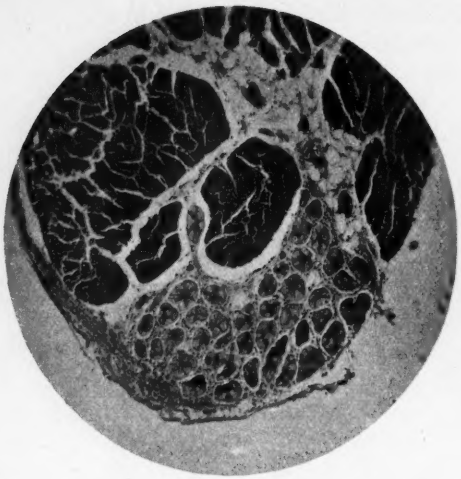


Fig. 2. Half the Moderator Band of a Sheep, in transverse section, showing the Right Branch of the A.V. Bundle. Purkinje fibres. (Low power.)

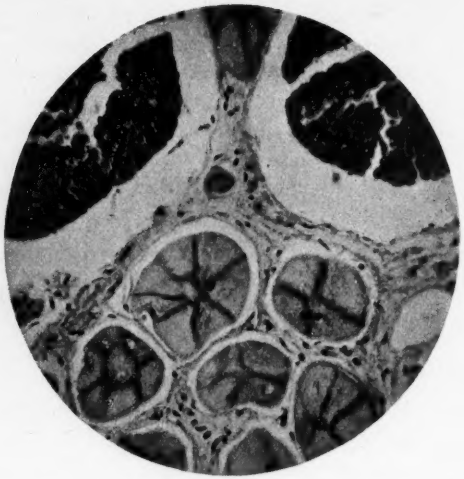


Fig. 3. Portion of Fig. 2, showing ordinary heart muscle, connective tissue sheath of the Purkinje fibres, the space round each fibre, the subdivision of each fibre into compartments by fibrils. (High power.)

Fig. 4. Longitudinal section of part of the Moderator Band of the sheep, showing Right Branch of A.V. Bundle. Purkinje fibres subdivided by longitudinal fibrils; connective tissue sheath for each fibre. Ordinary heart muscle. (High power.)

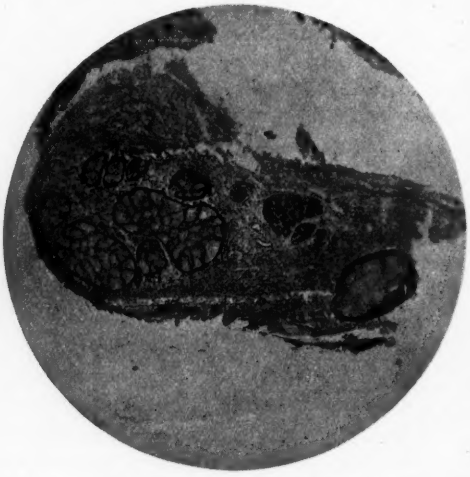


Fig. 5. Section across chorda of Left Ventricle from septum to anterior papillary muscle, in an Ox. Indian ink was injected into this chorda and flowed in a network under the endocardium of the outer wall of the ventricle. The ink surrounds each Purkinje fibre. A small bundle of ordinary heart muscle fibres is seen. (Low power.)

possible. But the connective tissue never penetrates into the walls of the compartments, as is readily understood when the fibrillar nature of these walls is realised. Often a space can be seen between the Purkinje fibre and its sheath, and in places a definite lining of very flat cells with elongated nuclei can be defined in this space. It is this space into which the Indian ink runs when the main Branch is injected, as microscopic sections clearly show in any part of the injected inner wall of the ventricle (fig. 5); again the true nature of the divisions of a Purkinje fibre into compartments is clearly seen, for no ink ever runs into the walls of the compartments.

Small non-medullated Nerves may readily be found in sections of either Branch of the Bundle, prepared and stained by ordinary methods (fig. 6); these Nerves may be seen within the outer sheath of the Branch, between the separate Purkinje fibres. Occasionally small groups of ganglionic Nerve cells are found in the closest proximity to the Purkinje tissue.

In the walls of the Ventricles the Purkinje fibres penetrate in places to a third or half the thickness of the wall; they were never found in the outer third, nor under the epicardium. As they leave the endocardium they usually follow a small artery, and become progressively smaller in all dimensions, till finally they are scarcely to be distinguished from an ordinary myocardial fibre, with which they can sometimes be seen to be in direct continuity. A definite sheath of connective tissue, and often small non-medullated Nerves, mark out the course of the Purkinje tissue.

In serial sections it is seen that the Bundle may either pass through the central fibrous body or round its right side; in the latter case it has to perforate the fibrous attachment of the septal cusp of the Tricuspid valve to the body, in order to reach the top of the ventricular septum. In Man the Bundle runs just below the pars membranacea septi; in those animals which show no membranous portion of the septum, the Bundle runs forwards and downwards just behind the angle of union of the septal and infundibular cusps of the Tricuspid valve.

The A.V. Node

The structure of the A.V. Node in the Sheep and Ox is quite different from that of the Bundle and its Branches (fig. 7). There is no distinct sheath of connective tissue but a fine reticulum of this tissue pervades the Node. The muscle fibres of the Node are more slender than those of the myocardium, in marked contrast with Purkinje fibres. They are multinucleated and stain less deeply with eosin than the myocardial fibre, but somewhat deeper than a Purkinje fibre. They show no undifferentiated cytoplasm, but consist of one to four fibrils running longitudinally through the fibre; the fibrils are often marked with cross striae. The fibres do not run in one direction but curve and anastomose freely, forming a syncytium in plexiform manner. Non-medullated Nerves are plentiful in the immediate vicinity of the Node, and in the Sheep and Ox are found actually within the Node and Bundle (figs. 8–10). Ganglia of Nerve cells are usually found several millimetres behind the Node (fig. 9).

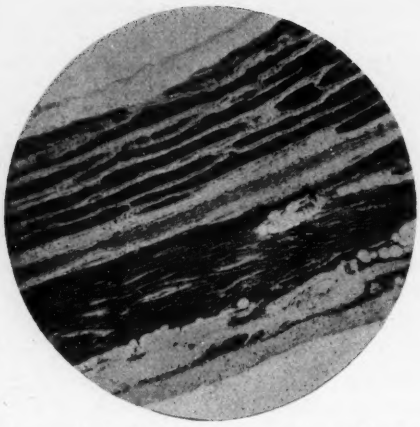


Fig. 6. Longitudinal section of the Moderator Band of a Sheep, showing a Nerve between the ordinary heart muscle and the Purkinje tissue which forms the Right Branch of the A.V. Bundle. The Nerve traverses the centre of the photograph. (Low power.)

Fig. 7. Transverse section of the A.V. Node in a Sheep, showing a syncytium of multinucleated fibres. (Low power.)

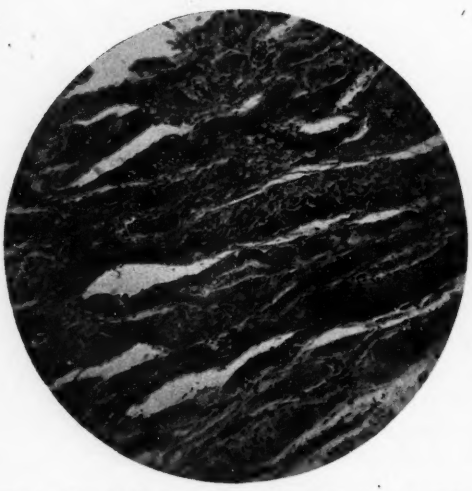


Fig. 8. Longitudinal section of the A.V. Bundle in a Calf, showing a profusion of Nerves among the Purkinje fibres. The densely nucleated strands are the Nerves. (Low power.)

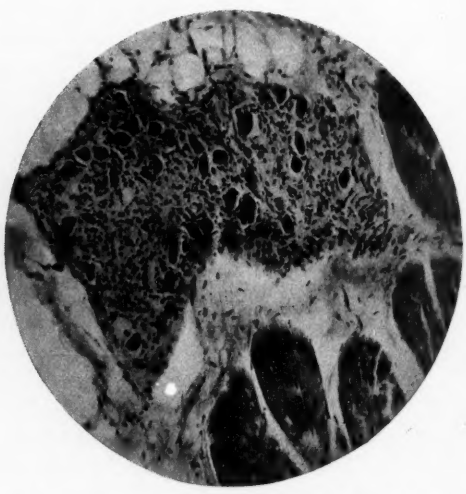


Fig. 9. Large ganglion of Nerve cells situated 4 mm. behind the posterior end of the A.V. Node in a Lamb. (High power.)

The adjacent auricular muscle fibres appear to fade gradually into the Node, but the continuity was not definitely established; in size and depth of staining the similarity may become so close that in places where a little connective tissue does not intervene, it is impossible to define just where auricular myocardium ends and Node begins. Anteriorly the fibres of the Node may be seen directly continuous with the Purkinje fibres of the Bundle (fig. 11), three or four Node fibres passing into one Purkinje fibre, which then widens out like a pear from its stalk, and shows fibrils in its periphery, with a clear central cytoplasm. Nerves are plentiful in the Bundle in the heart of the Calf, where they may be seen directly continuous with those of the Node in serial longitudinal sections. Occasionally there is an extension of the Node towards the base of the septal cusp, but this fades away in the fibrous tissue and does not form an accessory connection with the ventricle (cf. Curran(7)).

The S.A. Node

An exhaustive search of the auricles for Purkinje tissue has generally proved fruitless, but Keith and Flack(16) found a mass of tissue differing markedly from the rest of the auricles, and somewhat resembling the A.V. Node. This is situated to the right of the orifice of the Superior Vena Cava, in the upper part of the groove known as the Sulcus Terminalis. A comparative study led them to regard this specialised tissue as the remnant of the ring of tissue joining Sinus Venosus and Auricle in early foetal life, and hence it was called the Sino-Auricular Node.

The S.A. Node is elongated, being broadest above and tapering to a thin tail below. In its centre is an artery, around which the peculiar tissue of the Node is readily identified in transverse sections of the upper part of the Sulcus Terminalis (fig. 12). The amount of connective tissue is relatively greater than in the A.V. Node; the muscle fibres are smaller, and do not form such a clearly interlacing network; they are multi-nucleated and contain fibrils which at times clearly show cross striation. Though Nerves and small ganglia of Nerve cells are in close proximity to the Node, they are rarely seen within the Node to the same extent as in the A.V. Node.

Direct continuity of auricular and nodal fibres was not seen; at the margin of the Node the auricular fibres are in most places sharply delimited in bundles, but in other places it is difficult to define where the ordinary myocardium ends and the Node begins.

Findings in other Hearts

Lamb and Calf. The gross and microscopical anatomy is exactly the same as in the adult Sheep and Ox. Serial sections through the A.V. Node and Bundle *in situ* show very clearly the gradual transition from the ordinary myocardial fibres into the Node fibres; there is no sign of a connective tissue sheath isolating the Node. Nerves are plentiful in the Node, and Nerve cells in the immediate vicinity.

The striking fact about all the regions examined in the Calf was the abundance of Nerve structures; Nerves were readily found in both Nodes, in the

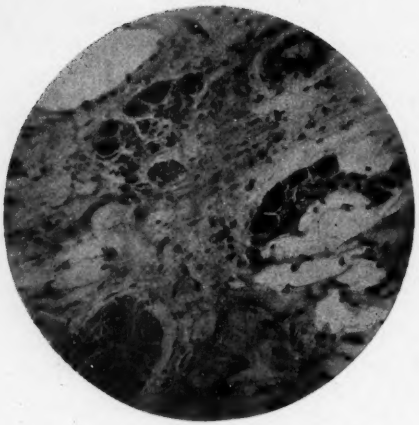


Fig. 10. Nerve cells and part of a non-medullated Nerve at the inferior margin of the A.V. Node of a Sheep. Nerve in left lower part of photo. (High power.)

Fig. 11. Longitudinal section through the junction of the A.V. Node and A.V. Bundle in a Sheep. In the centre of the photo a Node fibre is seen expanding into a Purkinje fibre of the Bundle. (High power.)

Fig. 12. Transverse section through the Sino-Auricular Node in a Calf. The central artery of the Node, and ordinary heart muscle adjoining the Node, are shown. (Low power.)

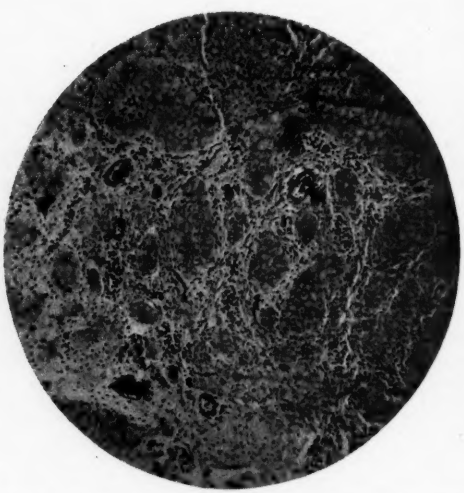


Fig. 13. Purkinje tissue in one of the Columnae carneae of the Right Auricle of a Calf—one of the only two instances in which Purkinje tissue was found in the auricles of any mammal. (Low power.)

Bundle, and in both main Branches of the Bundle. In two of the blocks taken from the Right *Auricle* of calves there appeared Purkinje tissue as distinct as in the Bundle or its Branches; one of these showed a small clump near the Superior Vena Cava, the other showed two columnae carneae in the roof of the Auricle consisting very largely of Purkinje tissue (fig. 13). These findings are notable as being the only mammalian Auricles in which any Purkinje tissue has been found by the writer.

Fig. 14. Human heart, dissected to show Right Branch of A.V. Bundle; a short portion is seen lying on black paper. Compare with fig. 1. A strip of black paper is lying in the gap left by cutting out the block from which the section shown in fig. 15 was taken. ($\times \frac{2}{3}$ nat. size.)

Pig. Both Nodes, the Bundle, and its Branches show the same structure and distribution as in the Sheep, but the compartments of a Purkinje fibre are usually smaller than those seen in the Sheep.

Gazelle. The same applies to the Gazelle. Both in the Pig and in the Gazelle the Nerve structures were less in evidence than in the Sheep.

Camel. Sections of the Right Branch of the Bundle as it ran along the Moderator Band showed great increase of connective tissue, with marked vacuolation of the Purkinje fibres, which were otherwise like those of the Sheep.

Man and Child. The topography of the Bundle and its Branches in the

human heart cannot with certainty be determined by dissection alone, nor yet by injection methods. Attempts to dissect even the main Bundle and Right Branch are often fruitless. Histology reveals the topography as following closely that in the Sheep and Ox, and also explains the difficulty of gross dissections and injections.

In the human heart there is rarely a distinct Moderator Band; the prominent Trabecula Supraventricularis represents the Band, and somewhere on the surface of this runs the Right Branch of the Bundle in its course from the septum to the anterior papillary muscle of the Right ventricle (fig. 14). Transverse sections of this Trabecula show a differentiated strand of muscle, totally unlike the Purkinje tissue of the Ungulate heart, but certainly representing that tissue; for serial sections show the continuity of this strand with the A.V. Bundle itself, and in the *A.V. Node* of the Sheep and Man there is very close agreement both in topography and minute structure. Very rarely the course of the Right Branch can be seen through the endocardium when the heart is opened, on account of its pallor which is mainly due to its sheath of connective tissue.

The Right Branch of the Bundle (figs. 15–17) is of varying shape as seen in transverse section of the Trabecula Supraventricularis; it may be distinctly ovoid and compact, triangular, or long and narrow. There is always more connective tissue around and within it than is found with a bundle of ordinary myocardial fibres, but no clear space is evident around the muscle fibres such as the space which contains the injection material around the Purkinje fibres of the Sheep. Nerve fibres are much more scarce than in the Sheep and Ox; Nerve cells were not seen in any of these sections. The muscle fibres themselves, totally unlike the Purkinje fibres of the Sheep, are very little larger than the ordinary myocardial fibres and often are actually smaller than these. They take the eosin less deeply on account of their cytoplasm being incompletely fibrillated. This scarcity of fibrils often gives them the appearance of being granular, and in many fibres the granules, which are fibrils in transverse section, are limited to the periphery of the cell, just as they are in the Purkinje fibres of the Sheep.

The left Branch of the Bundle is found in blocks from the left side of the ventricular septum, taken from half to one inch below the junction of the R. Coronary and non-Coronary cusps of the Aorta. It is never so compact as the Right Branch, but is of the same structure (fig. 19).

In sections from the outer wall of the ventricles it is rarely possible to identify the arborisations of the Branches of the Bundle. Sometimes small groups of cells like those in the main branches may be found just under the endocardium, but often not even a few small, pale, "granular" cells are seen, which cells might reasonably be considered as belonging to the Bundle system of fibres.

A number of blocks were cut from the Right Ventricle across the path of the Right Branch of the Bundle down the septum, at various places between

Fig. 15. Transverse section of R. Branch of A.V. Bundle in Man, on the trabecula supraventricularis, showing the connective tissue sheath, and the slight differentiation from ordinary heart muscle. The site of the block from which this section was cut is shown in fig. 14. (Low power.)

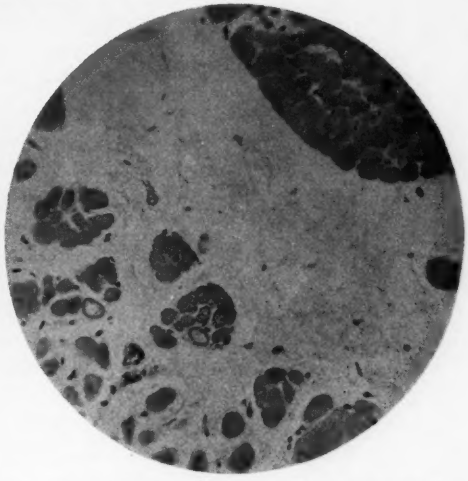


Fig. 16. Portion of fig. 15 more highly magnified to show the granules at the periphery of some of the fibres of the R. Branch of the A.V. Bundle—the human type of Purkinje fibre. (High power.)

Fig. 17. Transverse section of the trabecula supraventricularis in Man, showing a broad strand of Purkinje fibres (human type) under the endocardium, bounded and intersected by loose areolar tissue. The size, pallor, and clear centre of many of these fibres of the Right Branch of the Bundle form a marked contrast with the ordinary fibres of the myocardium. (High power.)

Fig. 18. Transverse section of the Right Branch of the A.V. Bundle in a Child, half an inch from its origin. The muscle in the centre of the photo, surrounded by open areolar tissue, and showing two veins, is the Right Branch. The photo illustrates the difficulty of identifying the Branches in Man, except by a study of serial sections in which the Branches are traced from the Bundle. (Low power.)

the pars membranacea septi and the origin of the Moderator Band or its homologue. In many of them no definite tract could be identified as the Right Branch, though the blocks were ½–¾ inch broad, and allowed for considerable variation in the course of the Branch. These hearts were compared with those human hearts which showed a definite Right Branch in sections from the same region, and with Sheep and Calf hearts in which the Branch was dissected, so that there is good reason for concluding that in some cases the Right Branch fades off into the appearance of normal muscle, without a sheath, soon after it has left the main Bundle (fig. 18).

In serial sections through the A.V. Bundle and its Branches in the heart of a child (Block LXXI) the Right Branch could only be followed for a distance of 2 millimetres. Frequently nothing but a study of serial sections enables one to identify the Branches of the Bundle 5–10 millimetres distant from their origin.

The A.V. Node and Bundle are best studied in serial sections of a block of tissue containing the adjacent portions of the auricular and ventricular septa, beginning just in front of the orifice of the Coronary Sinus, and ending in front of the pars membranacea septi. The Bundle is broader from side to side than from above downwards, so that it is more easily found in transverse than in longitudinal sections; the block is best cut from behind forwards.

There is no clear distinction between Node and Bundle in the human heart such as the change from Nodal to Purkinje tissue in the Sheep. The Node begins a few millimetres in front of the Coronary Sinus opening, its fibres becoming gradually differentiated from the auricular myocardium which overlies it, by their smallness, their pallor, their closely interwoven reticular arrangement, and their many nuclei (fig. 21). Traced forwards this type of muscle fibre becomes a somewhat oval mass lying between the auricular muscle and the central fibrous body. Into the latter mass are inserted the aorta, the aortic cusp of the Mitral valve, and the septal cusp of the Tricuspid valve. The Node either pierces the central fibrous body or runs round its right side; in the latter case it pierces the fibrous insertion of the septal cusp of the tricuspid valve. It then runs beneath the pars membranacea septi, and bifurcates beneath the anterior end of this structure (fig. 20).

The Sino-Auricular Node in the human heart is identified in sections of the upper part of the Sulcus Terminalis, chiefly by the position of a fibro-muscular mass around a large artery; the artery runs along the Sulcus and forms the landmark for the Node (fig. 22). The fibrous tissue of the Node is more abundant even in the Child's heart than it is in the Node of a Sheep, and the muscular fibres are less numerous; they do not form a distinct network, but appear to be intersected in very short lengths by the abundant connective tissue. Their fibrils may be seen to be cross striped. Non-medullated Nerves and small ganglia of Nerve cells are numerous in the vicinity of the Node, and in some sections ordinary stains reveal Nerves actually within the Nodal area. There is no definite boundary to the Node, but this fibro-muscular area fades off

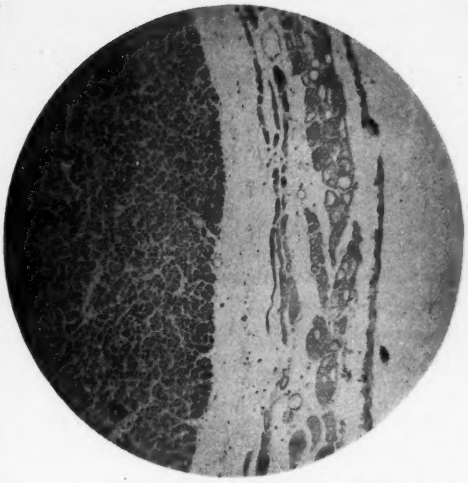


Fig. 19. Longitudinal section of the Left Branch of the A.V. Bundle in a Child. Purkinje tissue of human type is seen between endocardium and myocardium. (Low power.)

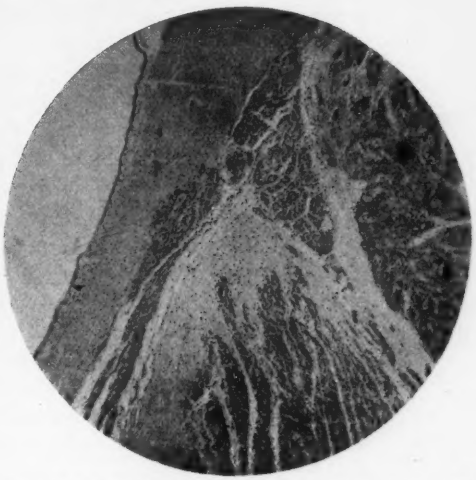


Fig. 20. Vertical section of the bifurcation of the A.V. Bundle in a Child. The section is just anterior to the pars membranacea septi. The aortic wall is seen on the left. The Bundle bestrides the fibrous summit of the Ventricular septum. The Left Branch of the Bundle extends to the margin of the photo. (Low power.)

Fig. 21. Transverse section of the A.V. Node in a Child. The close network of multinucleated fibres lies between the central fibrous body of the septa and the septal musculature of the Right Auricle. (Low power.)

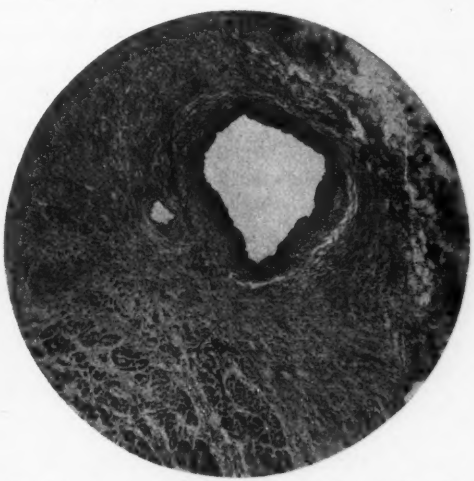


Fig. 22. Transverse section of the S.A. Node in Man. The central artery of the Node is surrounded by a dense mass of fibrous tissue in which are delicate muscle fibres. Ordinary myocardium is seen in the left lower part of the photo; epicardial fatty tissue on the opposite side. (Low power.)

gradually into the ordinary myocardium of the Auricle, the typical fibres of which are larger than the typical muscle fibres of the Node.

Rabbit. In serial sections through a Rabbit's heart the A.V. Node was identified topographically and structurally. There was more fat and less connective tissue than in the heart of Sheep or Man. The muscular fibres were small, pale, and rich in nuclei, but did not form so clear a network as in the hearts already described. No Nerves were recognised in the Node, but the inter-auricular septum, and region between the Pulmonary Artery and Aorta, were rich in Nerves and small collections of Nerve cells.

Under the endocardium of both ventricles many of the muscle fibres were smaller than usual, with less complete fibrillation, and stained less deeply; these closely resembled the smaller cells of the Branches in the human heart, though only in one place on the left side of the septum was there a collection of them that could be looked upon as the Left Branch; no Right Branch could be identified. Similar cells formed the bulk of several fine chordae crossing the Left Ventricle. They also occurred under the epicardium of both Auricles and Ventricles, a position in which Purkinje tissue was not found in Ungulates. Their relation to the A.V. Bundle is therefore very doubtful.

Guinea Pig. The differentiation of Nodal and Purkinje tissue was no more distinct than in the Rabbit. The Left Branch of the Bundle could be identified and also the A.V. Node.

Cat. The A.V. Bundle and its Right Branch were recognised rather from the topography of slightly differentiated strands than from any resemblance in structure to those of the Sheep. Their recognition was easier in the Kitten than in the Cat.

Monkey. The A.V. Node is readily recognised in serial sections, being very similar to the Node in the Sheep. No Nerves were found in the Node. The Right Branch was not identified, but the Left Branch was located by the same points as distinguished it in the Rabbit and Guinea Pig.

Hedgehog. The A.V. Node was very similar to that of the Sheep. Unlike the small hearts above described, the Bundle could be distinguished from the Node by the appearance of Purkinje tissue with very small compartments. The two Branches could only be identified by tracing their connection with the Bundle in serial sections.

REFERENCES TO THE LITERATURE

Prior to 1892 no muscular connection between the Auricles and Ventricles of the Mammalian Heart was known to exist. Kent's work was published in 1893 (1) in the same year that His (2) made known similar findings and gave his name to the Auriculo-Ventricular Bundle. In 1906 Tawara (3) published an exhaustive account of the Bundle in Mammals, and proved that the network of Purkinje fibres, which had been known since 1846 to exist under the endocardium of the sheep's ventricles, was in direct connection with the Bundle

of His through its Right and Left Branches. It was Tawara who emphasised the structure of that portion of the Bundle known as the A.V. Node.

Keith (4) and Keith and Flack (5) made a detailed study of the muscular connection between the various chambers of the vertebrate heart, which investigation led to the discovery of the Sino-Auricular Node.

The difficulty of dissecting the Bundle and Branches in Man is emphasised by several writers. Both Keith, and Curran (7) describe the fading away of the Right Branch on the septum until it cannot even be recognised by the microscope.

Josué (8) and Dietrich (9) give summaries of the early literature. Coloured figures and photos are given by Tawara (3), Fahr (10) and Monrad-Krohn (11). Miss de Witt's excellent reconstruction in wax of the Bundle and its arborisations is reproduced as a stereoscopic plate (12).

With the exception of Thorel quoted by Dietrich (9), no one has succeeded in demonstrating a specialised tract joining the S.A. Node and the A.V. Node; the fibres of the Nodes fade gradually into the ordinary auricular fibres as described by Cohn (13), Keith and Ivy Mackenzie (14), and Retzer (15).

The central artery of the S.A. Node comes from the Right Coronary Artery; no artery is found in the centre of the A.V. Node, but a special branch to the Node has been traced by Curran (7), Keith and Flack (16) and Monrad-Krohn (11) from the Right Coronary Artery. The present writer traced a branch to the Bundle from the Right Coronary Artery near its origin, and a branch to the Node running forwards in the Auricular septum from the Right Coronary Artery as it lies in the posterior A.V. Groove.

Nerves are not obvious in the Nodes and Bundle of Man, but those who have employed special methods, as de Witt (12), Morison (17) and Meiklejohn (18), have found a few small Nerves and some Nerve cells in the Bundle. In Ungulates, Nerve cells and Nerve fibres are more plentiful, as figured by Wilson (19), Engel (20), and Oppenheimer (21).

Robinson and Draper (22) found in Man that the Right Vagus is more powerful to affect the heart beat than is the Left Vagus, and that the Right Vagus seemed to control the rate, while the Left Vagus had more power over conductivity; and they surmised that possibly the Right Vagus is chiefly related to the S.A. Node, and the Left Vagus to the A.V. Node—a relation which I. Mackenzie (30) stated as very probable on the grounds of comparative anatomy and embryology.

The sheath of the Purkinje tissue has been specially studied by Curran (7), Lhamon (23), and Cohn (24). No injection results have been achieved in the human heart comparable with those in the beef heart.

Nagayo (25) found glycogen in the Nodal and Purkinje tissue of the lower mammals and Man; it is most plentiful in Ungulates.

The A.V. Node and Bundle was found by Tandler (26) in a 19·75 mm. human embryo: by Mall (27) in 10·20 mm. embryo; Mall found Nerves in the Bundle in a 13 mm. human foetus.

The comparative anatomy and embryology of the Bundle system has been

studied by Keith and Flack (5) and by Ivy Mackenzie (28, 30). Malformations of the Septum, and arrested development of the Bulbus, give rise to variations in the precise position of the Bundle, which serve to illustrate its mode of development (Keith (4, 29)).

No reference has been found to the presence of Purkinje tissue in the auricles of any mammal, such as is shown in fig. 13 of the present article.

Search has repeatedly been made for a muscular connection between Auricles and Ventricles other than the A.V. Bundle. Keith and Flack (16), Ivy Mackenzie (30) and Braeunig (31) failed to find a second muscular connection, but Kent in 1893 maintained that such existed, and has repeatedly demonstrated what he terms the Right lateral connection across the A.V. Groove (1, 32, 33, 34). He brings also experimental evidence in support of his histological findings. There is considerable evidence for such a connection in the clinical, experimental and pathological work of many writers, of which a full bibliography is given by Lewis (35).

My best thanks are due to Professor Elliot Smith, Professor Stopford and Professor Dean, in whose Departments this work has been done; and also to Mr H. Gooding of the Anatomy Department for the microphotographs.

REFERENCES

(1) Kent, A. F. S. "Researches on the structure and function of the mammalian heart." *Journ. of Phys.* XIII. pp. xxiii–xxiv; XIV. 233–254, 1893.

(2) His, Wm. Jr. "Die Thätigkeit des embryonalen Herzens und deren Bedeutung für die Lehre von der Herzbewegung beim Erwachsenen." *Arb. a. d. med. klin. zu Leipz.* 14–49 (cited by Tawara), 1893.

(3) Tawara, S. *Das Reizleitungssytem des Saugetierherzens*, etc. 8vo. Jena, 1906.

(4) Keith, A. "The auriculo-ventricular bundle of His." *Lancet*, I. 623–624, 1906.

(5) Keith, A. and Flack, M. W. "The form and nature of the muscular connections between the primary divisions of the vertebrate heart." *Journ. Anat. and Phys.* XLI. 172–189, 1907.

(6) Lewis, T. *The pacemaker of the mammalian heart.* 17th International Congress of Medicine, London, 1913, Section I, pt I. 107–119.

(7) Curran, E. J. "A constant bursa in relation with the bundle of His, with studies of the auricular connections of the bundle." *Anat. Record*, III. 618–631, 1909.

(8) Josué, O. *Les localisations cardiaques.* 17th International Congress of Medicine, London, 1913, Section I, pt I. 1–105.

(9) Dietrich, A. *Die Elemente des Herzmuskels.* 8vo. Jena, 1910.

(10) Fahr, Dr. "Ueber die muskulare Verbindung zwischen Vorhof und Ventrikel (das Hissche Bündel) in normalen Herzen und beim Adams-Stokesschen Symptom-Komplex." *Virchow's Archiv.* CLXXXVIII. 562–578, 1907.

(11) Monrad-Krohn, G. H. "Le faisceau atrio-ventriculaire dans le cœur humain." *Arch. du Mal. du Cœur*, IV. 350–357. Paris, 1911.

(12) De Witt, L. M. "Observations on the sino-ventricular connecting system of the mammalian heart." *Anat. Record*, III. 475–497, 1909.

(13) Cohn, A. E. "On the auriculo-nodal junction." *Heart*, I. 167–176, 1909–10.

(14) Keith, A. and Mackenzie, I. "Recent researches on the anatomy of the heart." *Lancet*, I. 101, 1910.

(15) Retzer, R. "Ueber die musculose Verbindung zwischen Vorhof und Ventrikel des Saugethierherzens." *Arch. f. Anat. u. Phys.*, Anat. Abth. 1–14, 1904.

(16) Keith, A. and Flack, M. W. "The auriculo-ventricular bundle of the human heart." *Lancet*, II. 359, 1906.

(17) MORISON, A. "On the innervation of the sino-auricular node (Keith-Flack) and the auriculo-ventricular bundle (Kent-His)." *Journ. of Anat. and Phys.* XLVI. 319–327, 1911–12.

(18) MEIKLEJOHN, J. "On the innervation of the nodal tissue of the mammalian heart." *Journ. of Anat. and Phys.* XLVIII. 1–18, 1913–14.

(19) WILSON, J. G. "Nerves of the atrio-ventricular bundle." *Proc. Roy. Soc.* LXXXI. London, 1909.

(20) ENGEL, J. "Beiträge zur normalen und pathologischen Histologie des Atrio-ventrikular-bündels." *Beitr. zur path. Anat.* XLVIII. 499–525, 1910.

(21) OPPENHEIMER, B. S. and A. "Nerve fibrils in the sino-auricular node." *Journ. of Exper. Med.* XVI. 613–619, 1912.

(22) ROBINSON, G. C. and DRAPER, G. "Studies with the electro-cardiagraph on the action of the vagus nerve in the human heart." *Journ. Exper. Med.* XV. 14–47, 1912.

(23) LHAMON, R. M. "The sheath of the sino-ventricular bundle." *Amer. Journ. of Anat.* XIII. 55–70, 1912.

(24) COHN, A. E. "Observations on injection specimens of the conduction system in ox hearts." *Heart,* IV. 225–227, 1913.

(25) NAGAYO, M. "Pathologisch-anatomische Beiträge zum Adams-Stokesschen Symptomenkomplex." *Zeits. f. klin. Med.* LXVII. 495–514, 1909.

(26) TANDLER, J. "The development of the heart." In *Manual of Human Embryology,* Edited by F. Keibel and F. P. Mall, vol. II. 8vo. Philadelphia, 1912.

(27) MALL, F. P. "On the development of the human heart." *Amer. Journ. of Anat.* XIII. 249–298, 1912.

(28) MACKENZIE, I. "Zur Frage eines Koordinationssystem in Herzen." *Verhandl. d. Deutsch. Path. Ges.* 90–118, 1910.

(29) KEITH, A. "The Hunterian Lectures on malformations of the heart." *Lancet,* II. 359, 433, 519, 1909.

(30) MACKENZIE, I. *The excitatory and connecting muscular system of the heart.* (A study in comparative anatomy.) 17th International Congress of Medicine, London, 1913, Section I, pt I. 121–150.

(31) BRAEUNIG, K. "Ueber musculose Verbindungen zwischen Vorkammer und Kammer bei verschiedenen Wirbelthierherzen." *Arch. f. Anat. u. Physiol.* Suppl. Bd 1–19. Leipzig, 1904.

(32) KENT, A. F. S. "The structure of the cardiac tissue at the A.V. junction." *Journ. of Physiol.* XLVII, p. xvii. 1913.

(33) —— "Observations on the auriculo-ventricular junction of the mammalian heart." *Quart. Journ. of Exper. Physiol.* VII. 193–195, 1913–14.

(34) —— "Neuro-muscular structures in the heart." *Proc. Roy. Soc.* Ser. B, vol. 87, 594.

(35) LEWIS, T. *The Mechanism and Graphic Registration of the Heart Beat.* 8vo. London, 1920.

BIFURCATE CLAVICLE

By HENRY RUTHERFURD, M.B., C.M.,
Glasgow

The subject of this abnormality was a youth of 16 years admitted under my care in the Royal Infirmary on 27th August last. He was said to have been assaulted the night before, and to have been struck a heavy blow on the left shoulder. There was swelling and ecchymosis of the posterior triangle of the neck in its lower part, and it seemed not unlikely that the clavicle had been broken.

There was also found some enfeeblement of both upper and lower limbs on the left side, and this was said to date from a depressed fracture of the skull eight months before. This is represented by a depressed scar in the right upper temporal region.

Fig. 1. X ray photograph taken with patient supine, plate in front of shoulder.

As the swelling over the shoulder subsided, a bony projection could be felt standing up from the line of the clavicle. Over this the skin could be slid smoothly, and it was thought that this might be the clavicle itself, or a displaced fragment of that bone. But there was no characteristic droop of the shoulder or disablement such as would have been expected had this been the explanation.

Skiagraphs showed that there were two clavicles or rather that the clavicle was bifurcate in its outer half, the upper branch running upwards and backwards from the middle of the normal one, which passed outwards to the acromion. That there is such a gap in the skiagraph between clavicle and acromion is to be accounted for by the cartilaginous condition of that process; ossification only beginning in the epiphysis there at 15 to 16 years.

On the 6th November the upper limb of the clavicle was removed by operation, its root on the main stem being easily cut with bone forceps. To the best of my judgment the part removed (now preserved in the Museum of the Royal College of Surgeons, England) presents the normal form of the clavicle in its external or lateral half, the conoid tubercle and ridge for the trapezoid ligament being represented on the undersurface. This in itself precludes our regarding the structure as an exostosis; to which is to be added the fact that its root was no nearer the sternal (epiphyseal) end than the acromion.

Splitting of the bone or detachment of its periosteum at the time of the earlier or later injury does not seem a reasonable explanation of the facts in view of the conformity to normal of the redundant part.

Skiagraphs of the opposite shoulder and of the pelvis show nothing abnormal.

A distinguished anatomist notes on the skiagraph which I sent him that the scapula is not normal, the coracoid being of more than normal thickness.

I know of no duplications of the long bones if the phalanges of the fingers and toes be excluded, that is to say, except in the extremities.

Professor Fawcett has shown that the inner and outer parts of the clavicle arise from separate centres. In this case the outer centre seems to have been duplicated and with the duplication appeared certain anomalies of the scapula. The condition is a rare one and we have been unable to find any previous record of the kind.

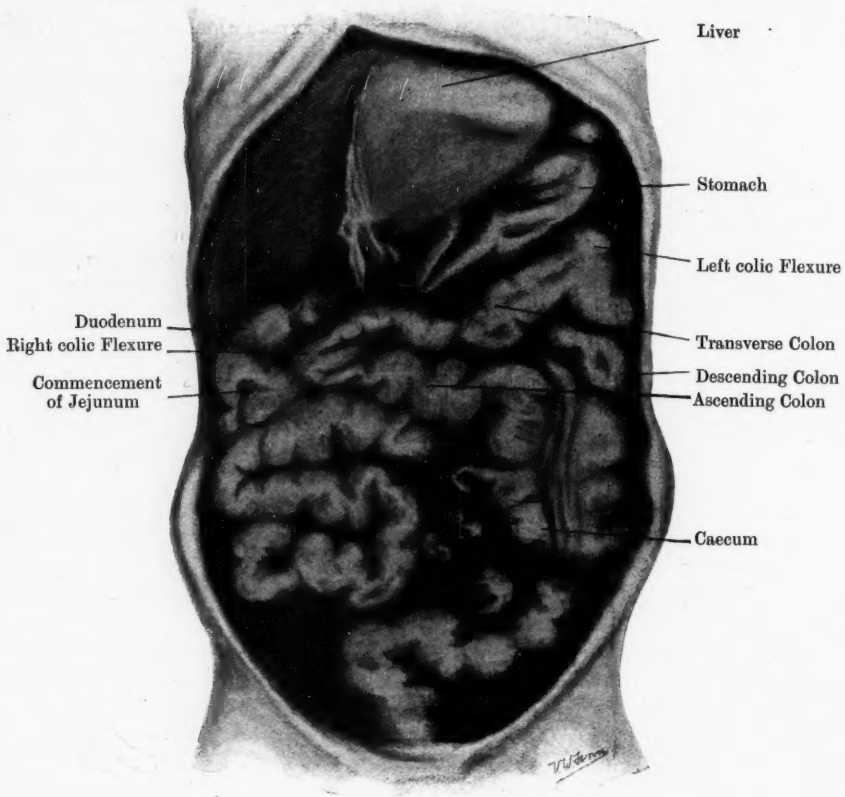
ABNORMAL DISPOSITION OF THE INTESTINAL TRACT

By N. PAN,

Professor of Anatomy, Medical College, Calcutta, India

Certain abnormalities were found in the disposition of the intestinal tract of an adult male subject brought into the dissecting room of the Medical College, Calcutta. As such abnormalities are rare, I am publishing a short note of them.

The stomach was very small and was normal in position. The superior and descending portions of the duodenum were normally placed, but the latter terminated abruptly in the jejunum on the right side of the third lumbar vertebra (see fig.). The mesentery crossed the vertebral column obliquely



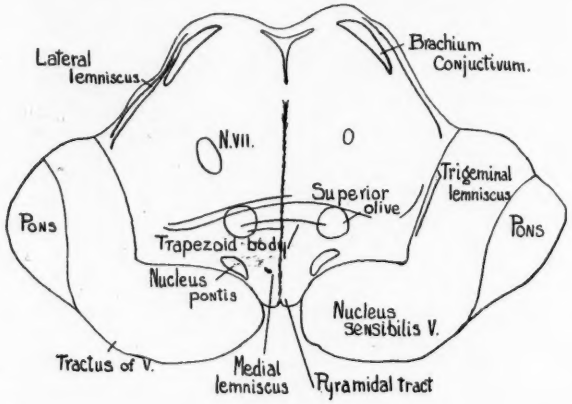
from the right to the left. The ileum terminated at the caecum situated in the left iliac fossa. The ascending colon crossed the vertebral column from the left to the right and ended in right colic (hepatic) flexure to the left of the descending portion of the duodenum. The transverse colon ended in the left colic (splenic) flexure and from there the descending colon was continued to the left iliac fossa concealed by the caecum on its left side.

This abnormal disposition of the intestinal tract was not associated with transposition of the thoracic or other abdominal viscera. The abnormal position of the vermiform process in the left iliac fossa is noteworthy from a clinical point of view as appendicitis occurring in such an individual would mislead the surgeon.

THE SUPERIOR OLIVE IN ORNITHORHYNCHUS

By MARION HINES, Ph.D.,
University of Chicago

In a splendid monograph (1) upon the bulb and midbrain of Ornithorhynchus published in 1901, Koelliker identified two larger nuclei in the medulla oblongata as the dorsal and ventral motor nuclei of the seventh nerve. He thought that a small nucleus lying midway between his "ventral nucleus of the seventh," and most medial part of the nucleus sensibilis of the fifth, was the superior olive. Consequently fibres which lay upon the outer part of the nucleus sensibilis and entered this nucleus he called the "trapezoid body." Ziehen (2), a few years later, wrote in the same sense, with the exception that he described a part of the trapezoid fibres as running laterally and dorsally to the nucleus sensibilis of the fifth. He also insisted that these fibres were the trapezoid body and not the pons, as Elliot Smith had identified them (3).



By a careful study of two excellent transverse series of this brain, one belonging to Professor Elliot Smith and the other to Professor J. T. Wilson, the following analysis was made. Koelliker's ventral nucleus of the seventh is the superior olive. Fibres connecting the two nuclei may be identified as the trapezoid body. The stria medullaris fibres may be traced from the larger dorsal nucleus of the eighth running with the root fibres of the seventh nerve. Fibres connecting the two nuclei can be identified. The stria medullaris runs from the larger dorsal nucleus of the eighth with the root fibres of the seventh nerve to the genu of the seventh and then turn ventral-ward to the body of

the olive. From this body the trapezoid fibres cross to the outer side lying dorsal to the nucleus sensibilis of the fifth. They are continued in this position as the lateral lemniscus until they reach the region of the inferior colliculus, when, turning dorsal-ward, they end in that body or, sweeping more lateral-ward, they are lost in the nucleus of the thalamus. The lateral lemniscus is interrupted by two nuclei. These nuclei, the lateral lemniscus and the colliculus, were beautifully demonstrated by Koelliker.

On the other hand Koelliker's "trapezoid body" is the pons and his "superior olive" one of the larger nuclei of that body (see fig., Nucleus pontis).

The accompanying outline, at the level of the superior olive and nucleus of the seventh nerve, will delineate the relations described above.

I would like to thank Professor Elliot Smith and Professor J. T. Wilson for the use of their material.

REFERENCES

(1) KOELLIKER. *Die Medulla Oblongata und die Vierhügelgegend von Ornithorhynchus und Echidna*, Leipzig, 1901.

(2) ZIEHEN. "Das Centralnervensystem der Monotremen und Marsupialier." Semon's *Zool. Forschungsreisen, Jenaische Denkschrift.*

(3) ELLIOT SMITH. *Journ. of Anat. and Physiol.* XXXIII. 325 (giving the history of this remarkable controversy, pp. 325–330).

THE EMBRYONIC CEREBRAL HEMISPHERE IN MAN

By MARION HINES, Ph.D.,
University of Chicago

The medial wall of the cerebral hemisphere of embryos 16 mm. to 30 mm. in length is not perfectly smooth. Its otherwise even contour is broken by a shallow groove, which extends from the olfactory bulb to the tip of the temporal pole. This is the fissura hippocampi, the "Bogenfurche" of His. The primordial hippocampus can be identified in embryos about 10 mm. in length by a thicker wall, a narrower matrix, and a more clearly defined marginal velum than the area immediately contiguous to it laterally. This region is separated from the area epithelialis by a sulcus limitans hippocampi.

The fascia dentata arises in the matrix of the ventral limb of the hippocampus as a group of deeply-stained cells, which migrate dorsal-ward into its marginal velum. The telencephalon medium is divided into terminal plate and roof by the angulus terminalis. The area epithelialis contiguous to the midplane-region differentiates into three characteristic areas, the septum ependymale, the area intercalata and the lamina epithelialis; that which lies contiguous to the main body of the lamina terminalis forms the septum.

In embryos of 16 mm. in length the ventro-lateral region of the hemisphere is very thick, containing two slight elevations, the medial and lateral roots of the corpus striatum. At this age the medial hillock is larger than the lateral. But in embryos of 20 mm. they are approximately equal in length and depth; and in those of from 27 mm. to 43 mm. the lateral hillock is the greater.

In early stages the cerebral hemisphere expands by intrinsic growth of each particular sector and especially by a marked extension of neopallial tissue. It elongates by acceleration of mid-line growth in the region of the lamina terminalis and the di-telencephalic fold, and by the expansion of areas of new tissue, which form the frontal, parietal and temporal poles. A study of histological differentiation in the early development of the telencephalon in man gives a method of measuring the relative growth of its several parts and thus of contributing to our knowledge of its intrinsic development.

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